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AN INVESTIGATION INTO THE IMPACTS OF ADDING AN AUTOMATED DAMAGE CONTROL SYSTEM TO A COAST GUARD 270' WMEC CUTTER

by

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September, 1997

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This study was carried out in three distinct parts:

1) A technology assessment of existing and proven damage control technologies for possible use on future Coast Guard vessels was conducted. Systems available commercially or through the US Navy were included. Long term R&D efforts were excluded from this study.

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3) The new design was compared to the existing baseline ship to investigate and determine the ship parameters impacted. Specifically, the parameters monitored were displacement, interior volume, cost, electrical load and manning levels.

Conclusions, concerning the potential value of an automated damage control system aboard ships, were drawn and presented in this report.

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AN INVESTIGATION INTO THE IMPACTS OF ADDING AN AUTOMATED DAMAGE CONTROL SYSTEM TO A COAST GUARD 270' WMEC CUTTER

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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I. INTRODUCTION

The operational readiness and mission effectiveness of Coast Guard vessels are directly affected by the ability to detect, assess, and correct damage inflicted by either accident or hostile actions. The damage is often inflicted with little or no warning, or erupts unexpectedly from machinery failure or human error. The ensuing damage control process is intensely manpower oriented and relies heavily on individual personnel training and knowledge. The entire ship's crew is thrown into the damage control evolution. Specialized crew members are relied upon to rapidly make the correct damage control decisions and the correct damage control actions must be carried out rapidly to prevent further damage to the ship or personnel. Typically, the damage control decisions must be made based on incomplete, uncertain, or old information.

As the Coast Guard proceeds toward more complex ships and ship systems, with smaller crews, an automatic means of detecting and responding to damage will be needed. The concept of an automated system responding to shipboard damage is a relatively new idea. The ability of systems to automatically detect, assess, and respond to damage could greatly reduce the burden on the smaller crew. The entire damage control evolution from detection to containment could be accomplished within seconds of detection and without the need for damage control personnel involvement. This idea could be implemented beforehand in the event of known impending damage, providing the best possible protection from the damage. An automatic damage control system could reduce present damage control training (typically the single largest training requirement).

Shipboard damage control has always been a very manpower intensive evolution and one previously thought to be impossible to automate. The recent increase in computing power and detection technology, at lower cost, make it worthwhile to reassess this conclusion. The concept of automated damage control has gained considerable favor as new ship classes are developed and reduced crew sizes are investigated. Since damage control personnel make up approximently 35% of the crew, reductions in crew size dictate reductions in damage control personnel.

A ship-wide automatic detection system could sense fire, smoke, flooding, and air quality (numerous other parameters are possible) continuously. Exact location, and type of damage can be determined by remote detectors. This damage control information can be displayed graphically in real time to all control stations allowing better decision making. Remote sensing of the progression of the damage can be incorporated in integrated monitoring and display subsystems.

An automated evaluation system can reduce cognitive load on the damage control personnel by providing suggestions for which damage control measures to initiate based on the nature of sensed conditions. Decision aids can monitor the situation and recommend responses based on well-defined DC tactics, procedures, and doctrine. Expert systems technology can be used to evaluate facts and their relative uncertainty and apply a set of rules to draw inferences that lead to possible problem solutions. This technique is similar to the way DC personnel receive information, evaluate its significance, and take corrective action based upon their training and experience. Stand alone software programs, such as Flooding Casualty Control Software (FCCS), may be called to perform detailed computations quickly. [Ref. 1]

An automatic isolation system can quickly isolate some kinds of damage and prevent further progressive damage. Remotely closing doors and hatches, ventilation closures, piping and electrical isolators can be employed to isolate the damage to the minimum area. Algorithms for load shedding and rerouting vital loads can be incorporated to limit losses of support systems. Automatic isolation may permit responses for the damaged compartment to be delayed until a more convenient time to address the damage. Remote material condition control can be accomplished.

A controlling reaction may be automatically initiated to assail the damage. Dewatering or extinguishing agents may be activated to assist in limiting the damage until fully manned damage control parties can arrive and properly tend to the situation. Damage control personnel may not have to actively attack the damaged compartments, avoiding the need for exposing themselves to the hostile environment of a raging fire or a flooding compartment.

New technologies need not be developed for these new systems. In fact several pieces of the puzzle already exist and are installed on-board ships today. Smoke, fire and bilge sensors are commonly in place and Flooding Casualty Control Software (FCCS) is available to calculate the effects of flooded compartments. These individual systems need only to be linked and utilized together to form the basis of an automated damage control system.

A. BACKGROUND

The United States Coast Guard currently operates a cutter fleet of approximently ninety major cutters (378's, 270's, 210's and 110's), plus a large number of buoy tenders and smaller cutters. Two major ship classes, 210's and 378's, are nearing the end of their useful service lives. The 270' is at its' mid-life. A current project is underway to replace these aging cutters. The Deepwater Mission Office, at Coast Guard Headquarters, is taking the lead in researching technology and policy changes that will have positive effects on the life-cycle cost of these new cutters. Manning levels are being scrutinized because they contribute heavily to a vessel's life cycle cost. Damage Control was one of several major shipboard areas identified as being extremely manpower-intensive and one where substantial savings could be realized by incorporating by new technologies. Typically, 27-35 % of a Coast Guard Cutters' crew is directly involved in damage control efforts, as shown in Figure 1.

The Navy has been exploiting new technology automation in the area of damage control area as well. Naval automation has recently received tremendous attention from the advances required by the Arsenal Ship and Smart Ship programs. New ship classes will embrace all available and applicable technology to better meet the mission demands with less crew to lower life-cycle costs. As one of the single most manpower-intensive evolutions, damage control automation is receiving quite a bit of attention to reduce manning levels. Any efforts to reduce the number of required crew is of great interest to Coast Guard and Navy.

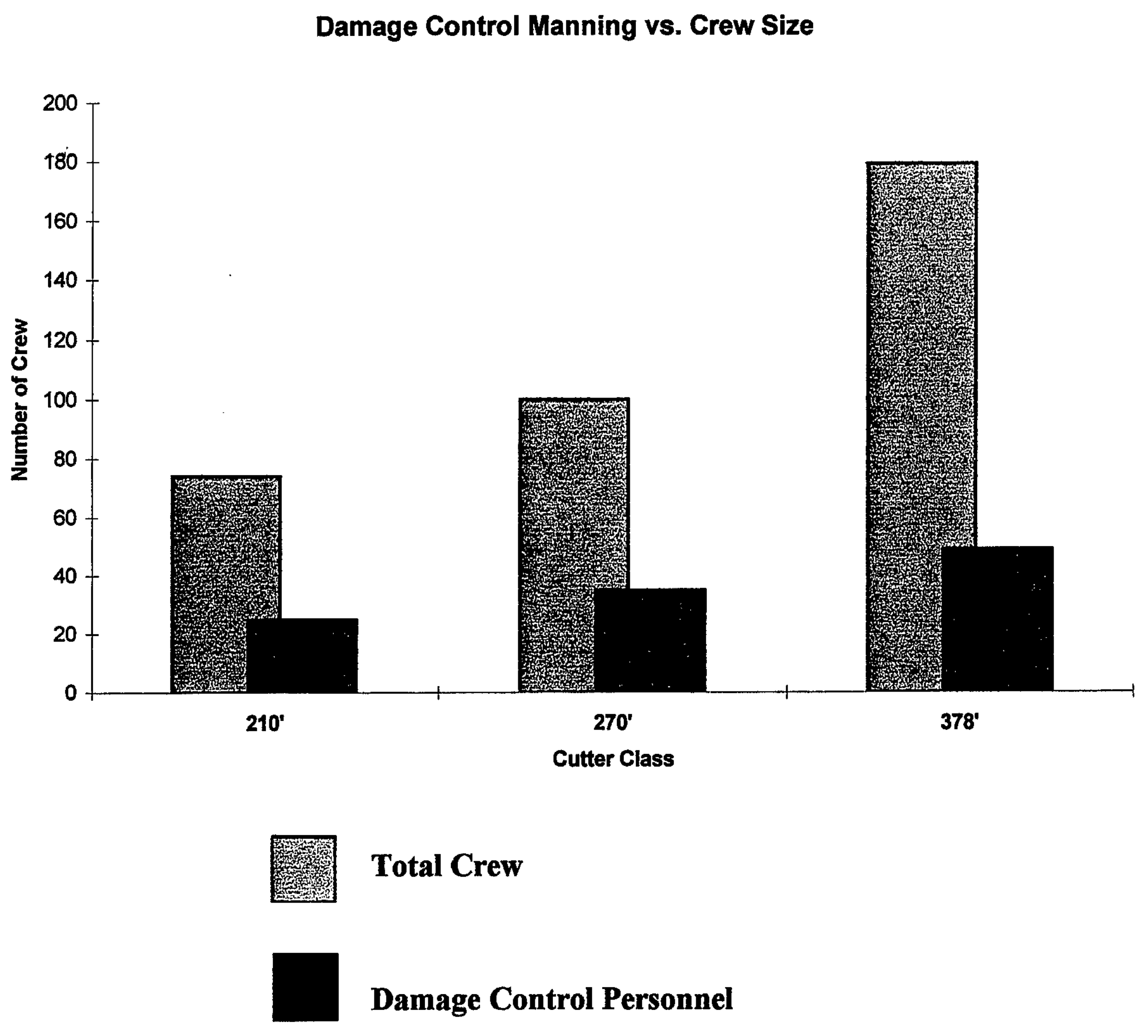

Figure 1 Typical Damage Control Manning vs. Coast Guard Crew Size

The 270' Medium Endurance Cutter class was selected as the baseline ship because of the relative youth of the design. It is the newest cutter class in the Coast Guard fleet. The ships were commissioned between 1983 and 1991. Information about the cutter and its systems is readily available. A software model of the cutter already exists in programs such as Advanced Surface Ship Evaluation Tool (ASSET) and Flooding Casualty Control Software (FCCS). The 270' class was originally designed to be minimally manned, with a crew of 100. The cutter was built with the latest technology of the 1970's . Conclusions drawn from the comparison would be considered applicable to

other platforms, and the information found would be useful in preliminary design considerations for a new cutter class.

B. OBJECTIVE

The purpose of this thesis was to investigate the impacts of adding an automated damage control system to a Coast Guard vessel. This study was initiated by a request, from the Coast Guard Deepwater Mission Project Office, to perform a technology assessment of existing damage control technologies. A follow-on preliminary automated damage control system design was developed to test the feasibility of such a system. Finally, a comparison between the baseline ship and the same ship with the preliminary system design was conducted to identify changing parameters that could be associated with an automated damage control system installation.

This study was carried out in three distinct parts:

1) A technology assessment of existing and proven damage control technologies for possible use on future Coast Guard vessels was conducted. Systems currently available commercially or through the US Navy were investigated. Near-completion research and development projects were investigated. Long term R&D efforts were excluded from this study. Technology not considered proven or available was eliminated from consideration.
2) A preliminary automated damage control system design was completed using the information found from the technology assessment. The design was completed using a Total Ship System design approach. A Coast Guard 270' Medium Endurance Cutter was the platform utilized. The design was formulated to test the feasibility of an automated damage control system in general. It was not intended as a retrofit design for the 270'Cutter. However, great effort went into ensuring the represented design was technically correct. The preliminary design was based upon emerging damage control systems being funded by Naval (United States and foreign) and commercial interests.

Several smaller systems have been installed on ships and were models for this design.

3) The new design was compared to the existing baseline ship to investigate and determine ship parameters impacted. Specifically, the parameters monitored were displacement, interior volume, cost, electrical load and manning levels. Information about the changes of these parameters could be beneficial to future designers considering automated damage control systems aboard ships.

A major emphasis of this research was to identify those areas that will be impacted with the increased automation. An objective of this study is to investigate the impacts to be expected in future ship designs with automated damage control systems. This study attempts to quantify some of the these expected changes in vessel parameters.

II. DISCUSSION OF AVAILABLE TECHNOLOGY

A technology assessment was conducted to ascertain the availability of proven damage control technologies, and capabilities. Specific manufacturers or suppliers were considered secondary to establishing that required needs could be met by today's technology. All damage control functional needs had to be addressed by the available systems and components. This survey focused on proven and available damage control components and systems, while excluding long term research and development programs.

In general, the functional capability of damage control sensors, systems and technology was found to be well established and mature. No single system was found that could provide all of the required damage control capabilities, however, combinations of individual systems can be combined to meet all the needs. No new technological advances need to be developed, only new policy and procedures addressing the use of automated damage control systems.

Most advances in the area of damage control systems are associated with advances in computational processing and extinguishment research. Computational processing improvements are leading to faster and more complex data processing, faster information networks, and better graphical displays. Extinguishing agent research has been bolstered by the Montreal Protocol banning ozone depleting substances, including halon, thereby forcing expediting research to provide suitable replacement agents.

This chapter summarizes the information gathered from the technology assessment and is presented by subject area. More detailed information, including basic theory of operation, manufacturer and component information, and more detailed sources of information are included in Appendices A, B & C.

A. DETECTION CAPABILITIES

Detection capabilities have dramatically increased in the recent years due to a large demand and use by the commercial sector. Individual sensors have become smaller, cheaper, and more rugged and reliable. Many manufacturers are producing the same types

of "standard" sensors and detectors, allowing interchangeability and compatibility between manufacturers. The commercial standard seems to be sensors operating on 12 and 24 VDC, 4-20 mA, and 0-100 Resistance Thermal Device (RTD) Ohm outputs to the data networks. Standardized sensors are highly interchangeable, cost less, and are already proven in many commercial applications. Other nonstandard sensors are available for specific needs. In situations where non-standard sensors are the only available choice or back-fitting is required, commercially available 'signal conditioners' can be utilized to convert the signal to a standard input type. The CG-47 "Smart Ship" program made extensive use of this technique and proved this method.

Table 1 provides a list of the available sensors required for the damage control process. Each sensor type, hazards detected by each, and the locations where each sensor would be used are provided. More detailed information about specific detectors is included in Appendix A, or can be obtained from two separate reports titled, "Alternative Approaches to Integrated Damage Control Systems (IDCS) for USCG Vessels" and "Evaluation of Non-Developmental Items (NDI) sensors" both by John J. McMullen Associates, INC. [Ref.2 & 3].

The various sensors listed in Table 1 would be used extensively throughout the ship to provide the greatest detection capability. All sensors would be 'hardwired' to a local processing center either directly through a data collection unit, or indirectly through other system controllers, such as the electrical switchboards or engine control panels. The wired connections can be configured as looped data networks providing a single information pathway for all the sensor data. Multiple loops can add redundancy and backup.

Sensors are provided with low voltage DC electrical power and data transmission inputs through data collection units. Each data collection unit can support up to 100 sensors, but typically one data collection unit supports only the sensors in a single zone.

The maintenance requirements associated with these sensors are very limited. Most sensors require only periodic testing and cleaning. New sensors and detectors are automatically monitored for changes in sensitivity caused by dirt, smoke, temperature, or

Sensor	Utilization	Detection/Range	Locations
Smoke	smoke detection	Ionization, photoelectric	ship wide
Flame	fire detection	IR, UV	ship wide
Heat	fire detection		ship wide
liquid level "on/off"	bilge alarm, flooding levels	Open/Closed	compartments below damage control deck
liquid level continuous level	tank levels: fuel, water, oils,	lengths up to 22'	ship's tanks
Oxygen	oxygen levels	0-25%	lower compartments
Carbon Monoxide	smoke/fire detection	0-500 ppm	ship wide
Carbon Dioxide	smoke/fire detection	0-1%	ship wide
Hydrogen	hydrogen gas	0-2000 ppm	battery rooms
Hydrogen Sulfide	sewage leaks, organic materials	0-50 ppm	sewage rooms, refrigerated stores
Freon	refrigerant leaks	0-1%	air conditioning & refrigeration (AC&R) spaces
Combustible Gas	explosion prevention	0-3%	pump rooms, paint lockers
PERC, numerous toxic gasses	specific sensor to additional toxic gasses	0-1000 ppm	compartments with localized hazards
Humidity & Temperature	heat stress calculations	0-100% Humidity 40-200°F	watch stations
Temperature	temperature sensitive spaces	40-200°F ± 1°	watch stations, magazines
Video	visual detection	n/a	unmanned spaces
Thermal	back up visual detection	± 1°	spaces with Closed Circuit Television (CCTV)
Contact switches	access closures	Open/Closed	All watertight accesses, critical actuators
Personnel	personnel accounting	IR	ship wide
Motion Detection	security issues	IR	ship wide

Table 1 Various Sensor Comparison

humidity. Advanced indication, of sensor sensitivity and the sensor address, is provided at the control panel prompting for a selected maintenance to be performed. Periodic cleaning is required of all smoke, fire and heat detectors and is based upon the operating conditions but should typically be an annual requirement. Some of the toxic gas sensors are consumable elements and have service lives of 1 or 2 years. Maintenance considerations have been designed into the new sensors and they are simple to install, service, and maintain. Specially designed maintenance tools allow personnel to remove and replace the plug-in sensors without using a ladder. These sensors also incorporate a built-in type identification so the detector system can identify the type and location of the sensor. Sensors also have built-in local testing capabilities, typically magnetic reed switches. Service life's of five years without failure are not uncommon. [Ref. 4]

Two new types of sensors will soon be available and deserve additional comment, FASTPAK 38 and LON works sensors. The FASTPAK 38 detectors have built-in extinguishment capability and release an extinguishing agent upon detection of a fire. This type of sensor/extinguishment package would be very effective in immediately applying an extinguishment agent after a positive fire detection. This unit could also be utilized in a temporary, portable mode and placed hazardous areas, such as welding sites to eliminate the need for fire watch personnel.

The LON works sensors are part of ongoing research at Florida Atlantic University. These "smart" sensors may provide better distributed sensing and processing capability, ultimately driving sensor system costs down drastically.

B. DATA NETWORKS

A capable and redundant data network is required to connect the sensors to the processing centers and control stations. In today's current market most computer network applications are PC based and the most utilized form is Ethernet. Several cable options were investigated including fiber optic, thick coax, thin coax and twisted pair. A report

titled, "Ethernet Options for the EX-USS Shadwell" by David Tate and Dr. Frederick Williams of the Naval Research Lab [Ref. 5], provides an excellent source of information on data networks for shipboard use.

The actual selection of the data network medium would depend on the entire automation package installed on the ship. The damage control network may be coupled with other highly information-dependent systems, such as combat systems, and may require a more robust network. The following, Table 2, is a comparison of the various network mediums considered.

Data Network Option	Advantages/Disadvantages
Fiber Optic Network	EMI resistant, lightweight, highly capable data transfer expensive, difficult to install
Thick Coax, 10base5	Highly capable, good signal integrity, intermediate cost, hard to install
Thin Coax ,10base2	light weight, low cost, easy installation susceptible to noise, smaller networks
Two Wire, 10baseT	very low cost, small networks noise and signal degradation

Table 2 Comparison of Data Network Mediums

For the purposes of this design, only considering the damage control needs, a thin coax Ethernet configuration was chosen as a good low cost solution. A more capable network could be added easily by using a combination of the thick and thin coax, utilizing the thick coax as the main trunk line with branches of thin coax.

This schematic, Figure 2, of the suggested thin net, is shown with directly connected sensors and sensors connected through data acquisition units. The computers represent processing units and control consoles.

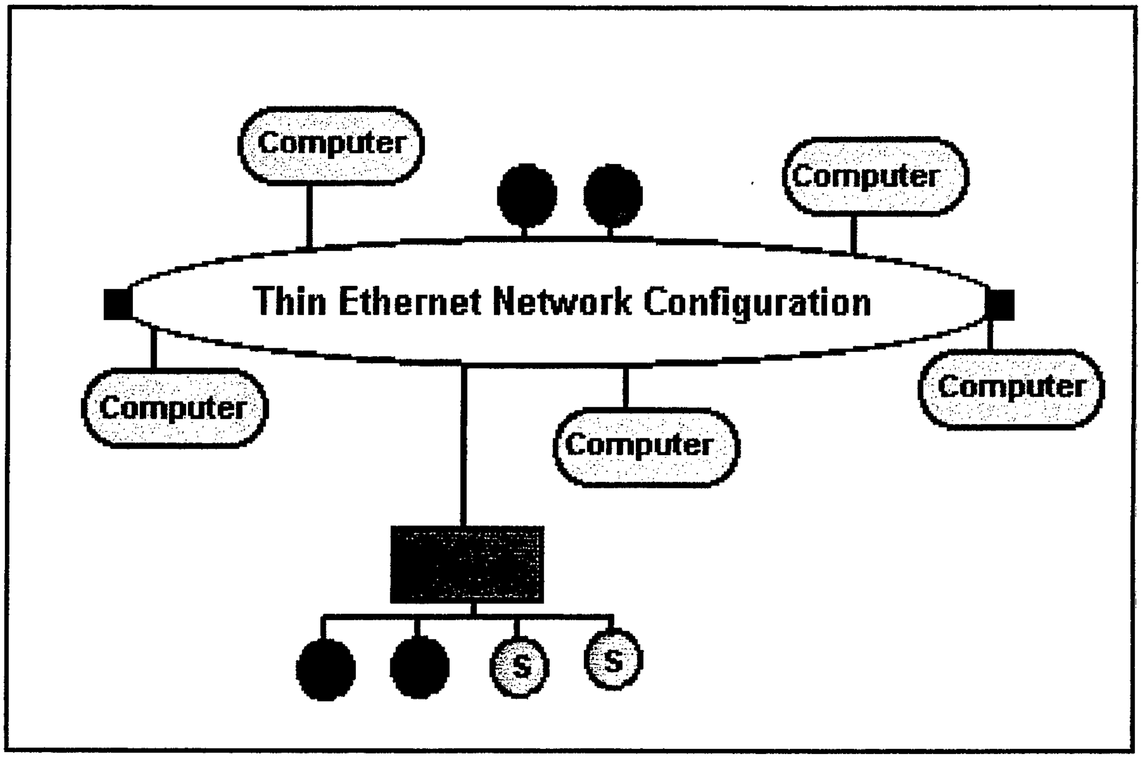

Figure 2 Schematic of Thin Ethernet Network

C. DETECTION DISPLAY

The sensor networks currently installed today are zonal configurations, providing sensor status to main alarm panels. Each zone corresponds to a group of several adjacent compartments, typically within watertight boundaries. The alarm panels indicate zonal sensor status by “red, yellow, & green” lights. Green indicates proper operation of the sensors, yellow indicates trouble with the sensor or system, and red lights indicate a positive alarm has been detected within the zone. The alarm is for the entire zone and does not provide accurate location, leaving damage control personnel to respond and search for the damage, as shown in Figure 3.

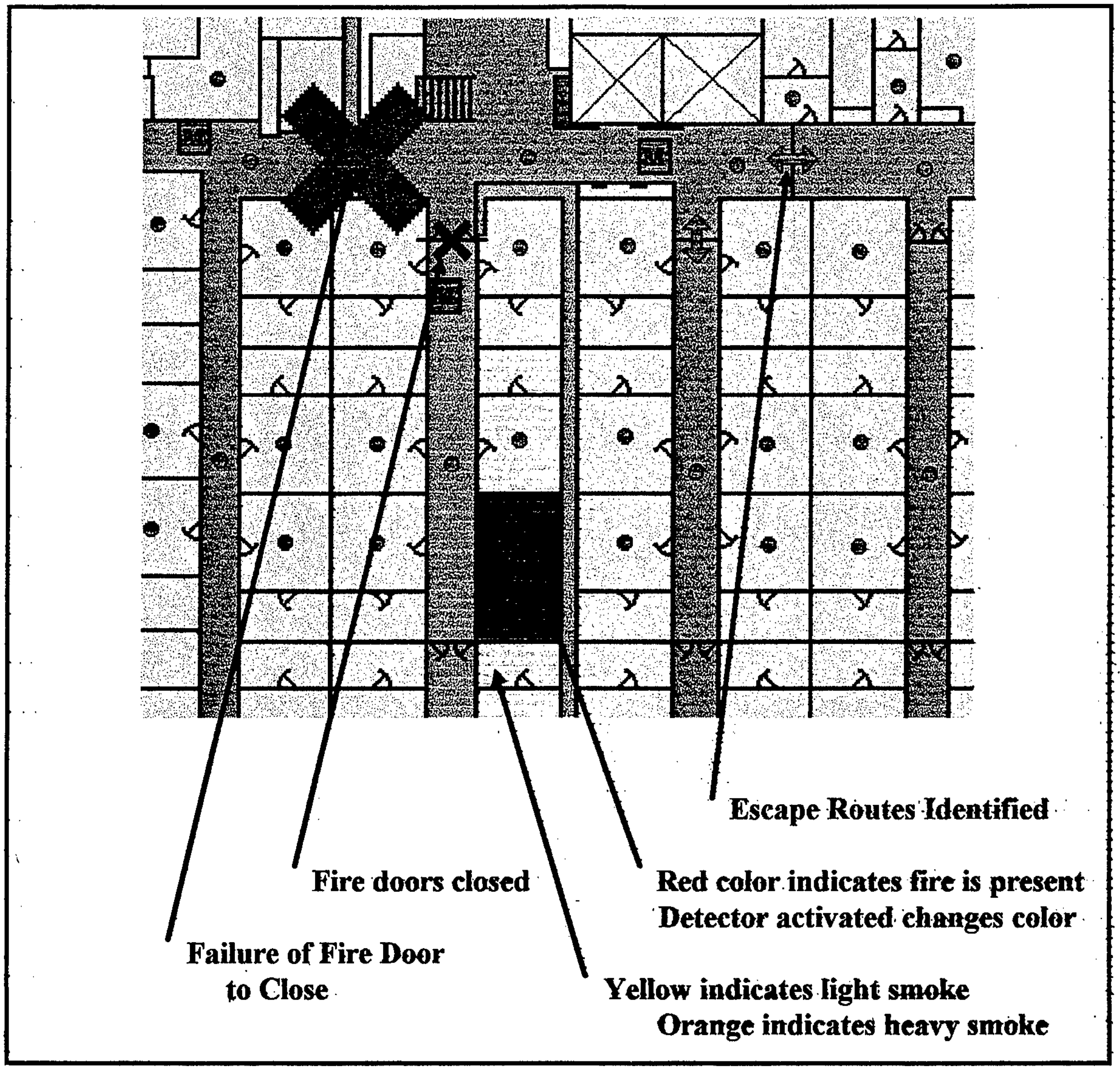

Figure 3 Typical Graphical Display of a Cruise Ship
(Autronica Marine AutoMaster 5000 [Ref. 6])

New detector systems provide the alarm status in color graphical displays. A computer screen is generated and updated by a processing unit, and displayed at all control stations in real time. Alarms are shown in a graphical, two or three dimensional representation of the ship. Exact location is given visually, quickly and precisely. Plan view or damage control plate graphics are available, providing instant visual recognition of the damaged compartment and surrounding spaces. Other pertinent information may also

be presented such as sub-system status, or personnel information. In the following, Figure 3, a typical display from a cruise liner, all detectors are shown with their current status. Fire doors status is also represented by the red and purple "X" indicating a closed door and a jammed open door, respectively. The fire is represented by red colored spaces, heavy smoke is given by orange, and light smoke is given by yellow. Large amounts of information are passed quickly and accurately by graphical representation.

Military shipboard applications typically require more information to be processed and displayed. Stability information, firemain status, combat system and propulsion plant status may be displayed at the same time, providing the best overall picture of the ship's condition, to enhance rapid decision making. Figure 4 shows this type of display capability.

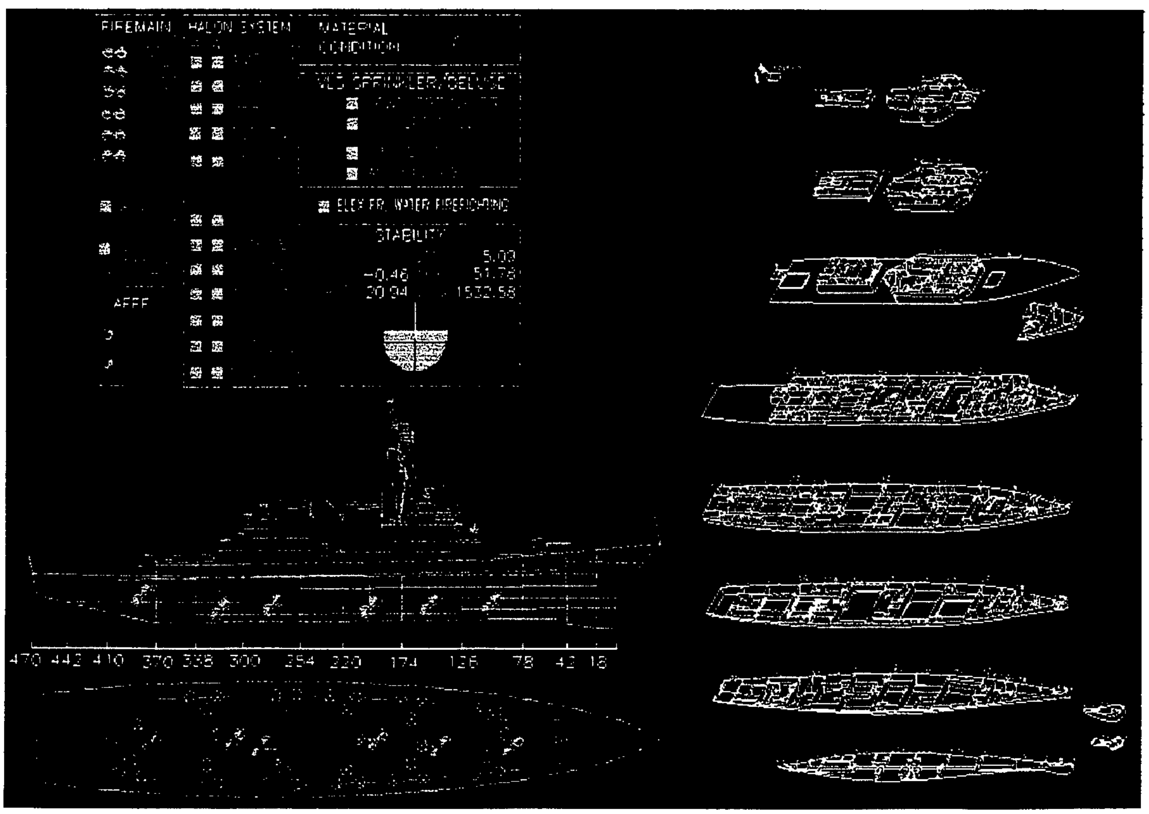

Figure 4 Typical Military Type Graphical Display
(DCS display by CAE Electronics [Ref. 7 & 8])

Several current systems were investigated and the following table is a summary of the systems. More detailed information about these specific systems is provided in Appendix B.

System Name	Advantages	Disadvantages
Damage Control System (DCS)	"DC plate" graphic displays, automatic links to FCCS & DCAMS, US Navy supported, actual systems operating, good sensor capability	no US vessel with complete system installed.
Two Wire Automatic Remote Sensing and Evaluation System (TWARSES	"DC plate" graphic displays, remote transmission capability, System operating on US Navy Ship, good sensor capability	no external links to other evaluation tools, limited number of sensors
Advanced Damage Control (ADCON)	portable "notebook" computer based,	poor displays, older system and technology, no external links to other evaluation tools
AutoMaster 5000	good 2D Graphic display, good watchstander interface, excellent maintainability	No external links to other evaluation tools, limited to fire and smoke detection (can be added)
EAGLE 2000	good watchstander interface, good sensor capability	poor display, no external links to other evaluation tools

Table 3 Comparison of Detection and Display Systems

Additional features such as information radio transmission to "non-attached" control stations allow remote watch standing. Currently, the Self Defense Test Ship (SDTS), utilizes this technology to eliminate the need for inport and underway watches on the vessel. Inport, ship's status is transmitted to the shore based duty section by telephone line. Underway the vessel is also unmanned and monitored from another platform in the vicinity by radio transmission.

Hand held wireless communicators, shown in Figure 5, have also been developed to allow onscene personnel to pass information, back and forth, to the control stations. Hand held personal information computers have been adapted for roving watch standers and damage control use. Onscene personnel have the ability to pass information into the damage control system removing the need for messengers and phone talkers. The damage control version transmits a "message blank" replacing the existing system where the investigators fill out message forms and hand carry them to a control station, to be manually entered into the system. Messengers are no longer needed, "copy errors" are reduced and all control station receive the same information in real time, providing a more complete damage control picture. [Ref. 9]

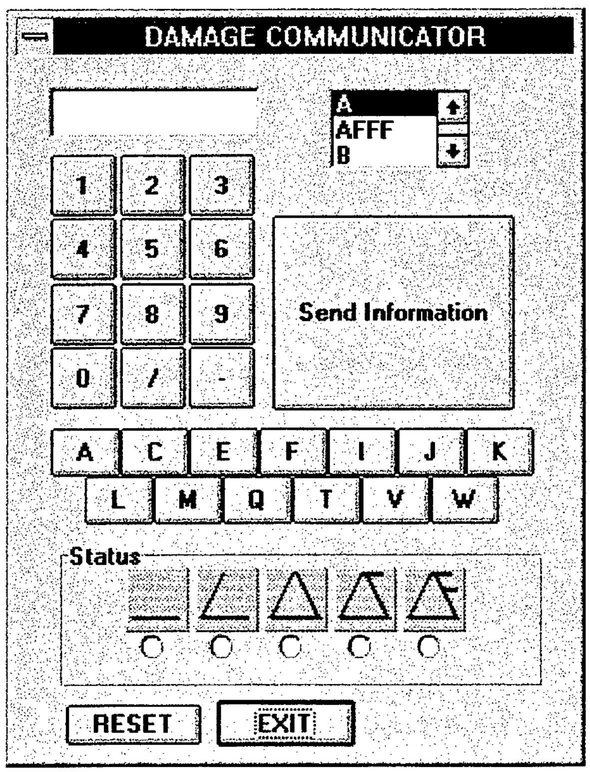

Figure 5 Damage Control Communicator

D. EVALUATION PROGRAMS

Specific information requirements are currently being addressed by additional standalone software programs. Damage Control Automated Managing System (DCAMS) monitors and controls all damage control sensor information and Flooding Casualty Control Software (FCCS) is currently used to calculate vessel stability. Other software programs provide Material Safety Data Sheets (MSDS), compartment isolation procedures, vital reroutes and casualty power information. FCCS is currently used aboard Coast Guard cutters on portable laptops, requiring manual input of damage information.

New damage control systems are providing automatic links to these software programs, speeding the information transfer and calculated results. The programs return the vital information to be displayed as part of the graphical sensor display. The information can be presented in a separate window or on a completely different display screen. The complete graphical display, presenting the current vessel status and other proactive damage control information, is maintained at each control station in real time. Damage control phone talkers and plotters are not required and any control station may function as the "master" station, providing redundancy and survivability.

The display and evaluation programs are available from several manufacturers including CAE Electronics, and Autronica. Damage Control System (DCS) by CAE Electronics is one of the available damage control packages that would apply directly to a Coast Guard or Navy application. DCS can also be pre-programmed to enact a sequence of events in response to the damage detected. Automated actuators and controllers can be manipulated to carry out various taskings, to prevent further damage to the vessel. Each pre-programmed sequence of events would be in line with current damage control policy and doctrine, ensuring a proper response to damage. A system like this is installed on the Israeli SAAR IV corvette which automatically detects and removes bilge water accumulation. Rate of rise of the water level is monitored and for normal situations the water is removed to a waste oil tank, however, if rapid water rise (flooding) is detected, the water is pumped directly overboard. This is accomplished in a fully automatic mode

without crew member involvement. This same thought process can be applied to fire and toxic gas situations as well. While this type of damage control system is not common on US Navy ships, several companies do provide these systems and several foreign navy ships have them installed. CAE electronics is currently contracted to install versions of these systems on several Navy ships including LPD-17.

E. ISOLATION CAPABILITY

Quick damage isolation is key to limiting damage to the smallest area possible. The preprogrammed responses mentioned in the previous section rely on the ability to contain the damage. The ability to automatically "close up" an entire compartment, by closing the major accesses, can prevent any further damage. The major accesses are doors, hatches and ventilation openings. In order to automate this portion of the process, self activated doors and hatches and remotely operated valves are required. Hydraulic doors and valve controllers are available, and currently used; however, only one manufacturer of hydraulic hatches was found. The hatch is very important in limiting the vertical rise of the damage. The watertight doors and hatches operate on individual hydraulic or pneumatic actuators. Theses fittings do not require personnel to operate, and can be remotely opened and closed. Sensors are installed to detect the fitting's status, open or closed. In situations where required, the fittings can be forced shut and locked, remotely. Crew members would not have to secure doors and hatches around the damaged compartment, as is typically done. Personnel "closed in" by this automatic action would have separate manual escape scuttles to evacuate. The door and hatch in Figure 6 can be powered by hydraulic or pneumatic means. [Ref. 10]

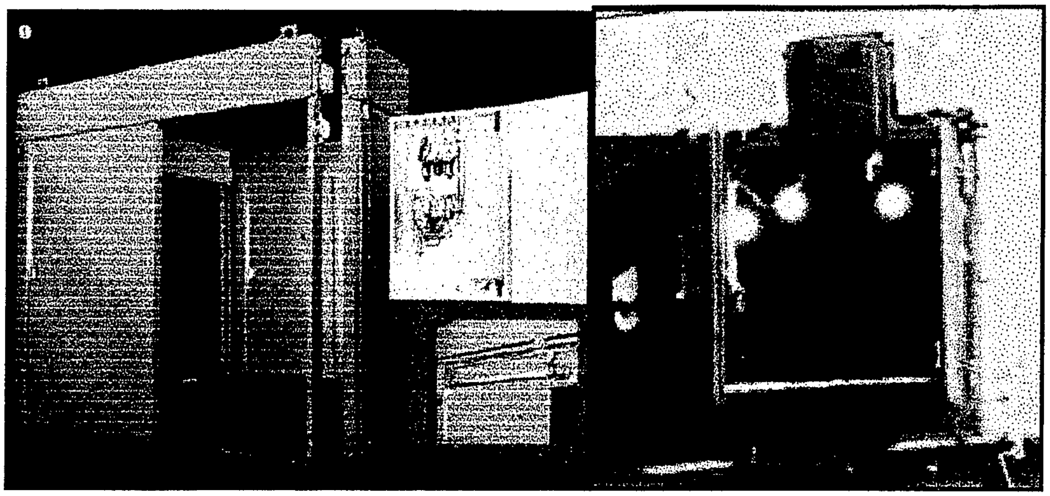

Figure 6 Pictures of Hydraulic Watertight Doors and Hatches

F. REACTIVE SYSTEMS

The last requirement for the Automatic Damage Control System is the ability to provide a controlling action to limit the damage to the compartment or the ship. This controlling action would be activated as an extinguishing agent for fire scenarios. Flooding would be controlled by the automatic initiation of de-watering pumps and toxic gas situations addressed by automatic ventilation control are addressed procedurally.

1. Fire Suppression

Extinguishing agent research has recently been increased to find a suitable replacement for halon. Several classes of agents, including halocarbons, inert gases, water sprinklers, and aerosol generators, have been developed and tested. All listed agents were shown to be effective in extinguishing two dimensional fires and some were effective in three dimensional.

Agent	Extinguishment Concentration	Advantages	Disadvantages
Halocarbons			
Halon 1301	5%	n/a	n/a-
CAE-410	6-7%	safe for personnel and no clean up	requires compressed storage and expensive
FM-200	16%	safe for personnel and no clean up	requires compressed storage and expensive
FE-13	6.4%	safe for personnel and no clean up	requires compressed storage and expensive
FE-36	8.5%	safe for personnel and no clean up	requires compressed storage and expensive
FE-241	10.9%	no clean up	toxic, expensive, and requires compressed storage
FE-25	11.9%	no clean up	toxic, expensive, and requires compressed storage
NAF-S-III	2.0	no clean up	toxic, expensive, and requires compressed storage
FIC-1311	3.6	no clean up	toxic, expensive, and requires compressed storage
Chemical			
Nitrogen (IG-100)	40%	no thermal byproducts and no clean up	low oxygen and requires compressed storage
Inergen (IG-541)	37.5%	no thermal byproducts and no clean up	low oxygen and requires compressed storage
Argonite (IG-55)	33.6%	no thermal byproducts and no clean up	low oxygen and requires compressed storage
Argotec (IG-01)	38	no thermal byproducts and no clean up	low oxygen and c requires compressed storage
Water mist	n/a	minimal cost and good extinguishment	clean up concerns
Fine Particle Aerosols	Various	good extinguishment	clean up concerns and possibly toxic

Table 4 Comparison of Various Extinguishment Agents

Table 4 is a list of the agents available that could be deployed as halon alternatives. No "drop in" replacements are available due to the nozzle and mixing requirements. All agents require complete change-out from old halon systems.

Water mist is the logical choice for a ship wide fire extinguishment agent. Water mist works on the principle of reduced water droplet size. Since heat absorption is a function of surface area, not volume, smaller droplets mean more surface area, resulting in faster heat absorption. The smaller droplets also aid in oxygen dilution around the fire area. Very low water flow rates and only intermediate pressures are required to produce the small droplets. While any water, fresh or salt, can be used in the water mist system, fresh water is preferred for clean up considerations. Fresh water (and Sea water) is readily available aboard our ships and has proven highly successful in extinguishment of all classes (A, B, & C) of fire. Water mist has been tested extensively in the recent past and has recently been approved for commercial shipping fire protection. The Coast Guard Research and development Center has taken the lead in testing this technology and approving it for use. Extensive and detailed information is available on this technology and is available in several reports included in Appendix C. [Ref. 11 & 12]

2. Toxic Gas or Smoke

Toxic gas and, to some extent, smoke situations would be handled by ventilation procedures. This would involve setting up negative ventilation to the affected compartment and positive ventilation to the surrounding compartments. Combustible gasses would dictate positive pressure techniques to be utilized. The troublesome gas would be vented to the exterior of the ship. Alarms and isolation of the compartment accesses would be controlled, to not let any crew members enter the space. Personnel in the compartment would be notified of the situation through local audio alarm and escape through the manual escape scuttles.

Careful design of the ventilation systems to allow individual compartmental ventilation settings is required. The ventilation systems should be a zonal configuration,

with multiple fan locations, providing redundant supply and exhaust configurations. This is a common practice on commercial vessels with automated ventilation control.

3. Flooding

Flooding of a compartment would be contained by the isolation system and by the nearest watertight bulkheads, limiting the damage to the main watertight boundaries. The hydraulic hatches and water tight decks would limit vertical progressive flooding. Installed drainage systems within the compartment would be activated to remove as much water as possible. Lowest compartments are realistically lost upon initial damage and rapid isolation is the only preventative measure.

Most of the flooding containment is built passively into the vessel and should be considered carefully as part of a new design. Loss of a watertight zone from the keel to the margin line is a typical design constraint for determining the floodable length of a vessel. An automated isolation system can prevent this type of assumption and keep additional buoyancy intact after damage.

Design of the installed drainage system must be considered carefully, adding de-watering capacity to low compartments. System configuration should provide remote valve operation to de-water individual compartments.

A naval Foam-in-Salvage system is available to re-float sunken ships. This system injects foam into flooded compartments to exclude water and restore lost buoyancy. Modifications can be made to utilize this systems during a flooding incident, restoring the lost buoyancy.

All of the systems and capabilities discussed in this chapter are developed and tested, unless noted otherwise. It is conceivable to design an Automated Damage control system using this technology today. The next chapter discusses a conceptual design that was formulated using this information.

III. AUTOMATED DAMAGE CONTROL SYSTEM DESIGN

The concept of automating the damage control process was initiated by several smaller advances in detection and assessment capability. Today's vessels already rely on remote smoke, fire, and bilge level sensors to warn of impending problems. Stability software is utilized to quickly and accurately calculate stability after damage. These tools were developed to assist the damage control personnel in making decisions.

An Automated Damage Control System (ADCS) would utilize many of the capabilities described in the previous chapter. Additionally, it is possible to automatically carry out a predetermined action, providing an initial response to control the damage. The pre-programmed actions would be based on standard damage control policy and procedures, but would be performed more rapidly. Much of the damage control process can be automated by reliance on computer technology to detect, assess, isolate, and initiate initial actions against the damage. Smaller numbers of damage control personnel would be given the opportunity to prioritize damage and assets, responding where needed most.

The design utilized in this thesis, was developed using a Total Ship Systems Engineering (TSSE) design approach. This process considers the ship as a large system made up of smaller subsystems. The effects of the subsystem designs and interactions are considered in relation to the rest of the overall ship design, thus developing a superior design over the conventional conglomeration of independent subsystems. This approach improves the life cycle cost effectiveness, provides strategic quality assurance within the design, and improves the efficiency of the design process, resulting in a smaller, more highly integrated and capable vessel. [Ref. 13]

A. PRELIMINARY DESIGN DESCRIPTION

A preliminary ADCS design was developed using information found from the technology assessment. Only proven and available damage control systems were

investigated. All technological needs and functions, were found to be existing in one system or another. However, no single system was found to meet all of the required needs. Desired capabilities of the various systems were individually captured and applied in the design. It is proposed that future system upgrades will incorporate these needs without significant R& D research. Functional capability is already proven and available in systems today. The preliminary ADCS design is described below. Information about the systems from the technology assessment are included in Chapter IV.

1. Detection System

A ship-wide array of sensors allows continuous monitoring compartment by compartment. Pinpoint detection will indicate the exact location of the damage. Progressive damage or changes in damage will be updated or reported in real time. Controlling actions can be directed to the exact area where required. The speed of the response will be greatly increased by eliminating the need to search for the damage within present detection zones.

Each compartment will be monitored by multi-sensor fire detectors. Smoke and fires will be detected by photoelectric smoke, ultraviolet flame, carbon monoxide and temperature sensors. Monitoring of a fire's progression from the first smoke, through the initiation of the flame, until ultimately the detector is physically damaged, is accomplished with this detector array. Various alarm thresholds can depict different conditions from the same sensor. A single optical detector is capable of monitoring a single compartment (up to 25 meters in diameter), minimizing the number of required detectors. Exact placement and number of detectors will be based upon actual ship configurations. Safety of Life at Sea(SOLAS) guidelines were used in determining the type of fire and smoke detectors required in each space. The following table is a summary of these requirements.

Compartments located below the damage control deck will also be monitored for flooding by liquid level detectors. Flooding detectors consist of multiple sensors located

Area	Detector Type				
Accommodations	**Smoke**	**Smoke**	**Smoke**	**Heat**	**Flame**
	Ion	**Optical**	**Exi / Ion**	**Diff.**	**IR/UV**
Corridors		X			
Cabins		X			
Escape Routes		X			
Hospitals		X			
Lockers		X			
Mess Rooms		X			
Offices		X			
Pantry		X			
Stores		X			
Service Spaces					
Galley				X	
Pantry				X	
Storerooms		X			
Workshops	X				
Control Stations					
Emergency Gen Room	X				
Main Fire Station		X			
Navigation Bridge		X			
Radio Room		X			
Machinery Spaces					
Engine Control room	(X)	X			
Aux Engine room	(X)	X			(X)
Main Engine room	(X)	X			
Electrical Workshop	(X)	X			
Electrical Stores	(X)	X			
Engineering Workshops	(X)	X			
Engineering Stores	(X)	X			
Stabilizer Room	(X)	X			
Sewage Room	(X)	X			
Pump rooms	(X)	X	(X)		
Technical Areas					
AC Vent rooms	X	X			
Battery room		X	X		
Bow Thruster	X				
Paint Stores			X		
Switchboard rooms	X				
Elevator rooms	X				

Table 5 SOLAS Guidelines for Fire Detection Design

from bilge level to overhead. Stability information can be calculated by the use of seven sensors per compartment. The sensors are located to indicate the presence of liquid, at 2 and 6 inches, and then flooding is monitored by sensors at 10%, 25%, 50%, 75%, and 100% of the compartment height.

Important parameters about ship status will be monitored as well. Critical valves and compartment accesses will be monitored for exact material condition present. Compartments will be monitored for humidity and temperature, to calculate heat stress. Paint lockers and pump rooms will be monitored for explosive gases and lack of oxygen. Sewage spaces will be monitored for hydrogen sulfide gas. Battery rooms will be monitored for hydrogen gas. Air conditioning and refrigeration rooms will monitored for refrigerants and low oxygen levels. Other appropriate monitoring will be conducted in spaces subjected to localized hazards. Figure 7 is a depiction of how a typical compartment would be monitored.

These levels of monitoring represent increases from those typically performed today. Monitoring confined areas subject to toxic gas or oxygen deficiency will prevent unwanted exposures of the crew to these hazards. Immediate notification to control stations will prevent unaware watch standers from entering the compartments.

For a 270' Cutter, approximently 445 sensors would be required to carry out the level of monitoring discussed above. The following breakdown is a summary of the required sensor information.

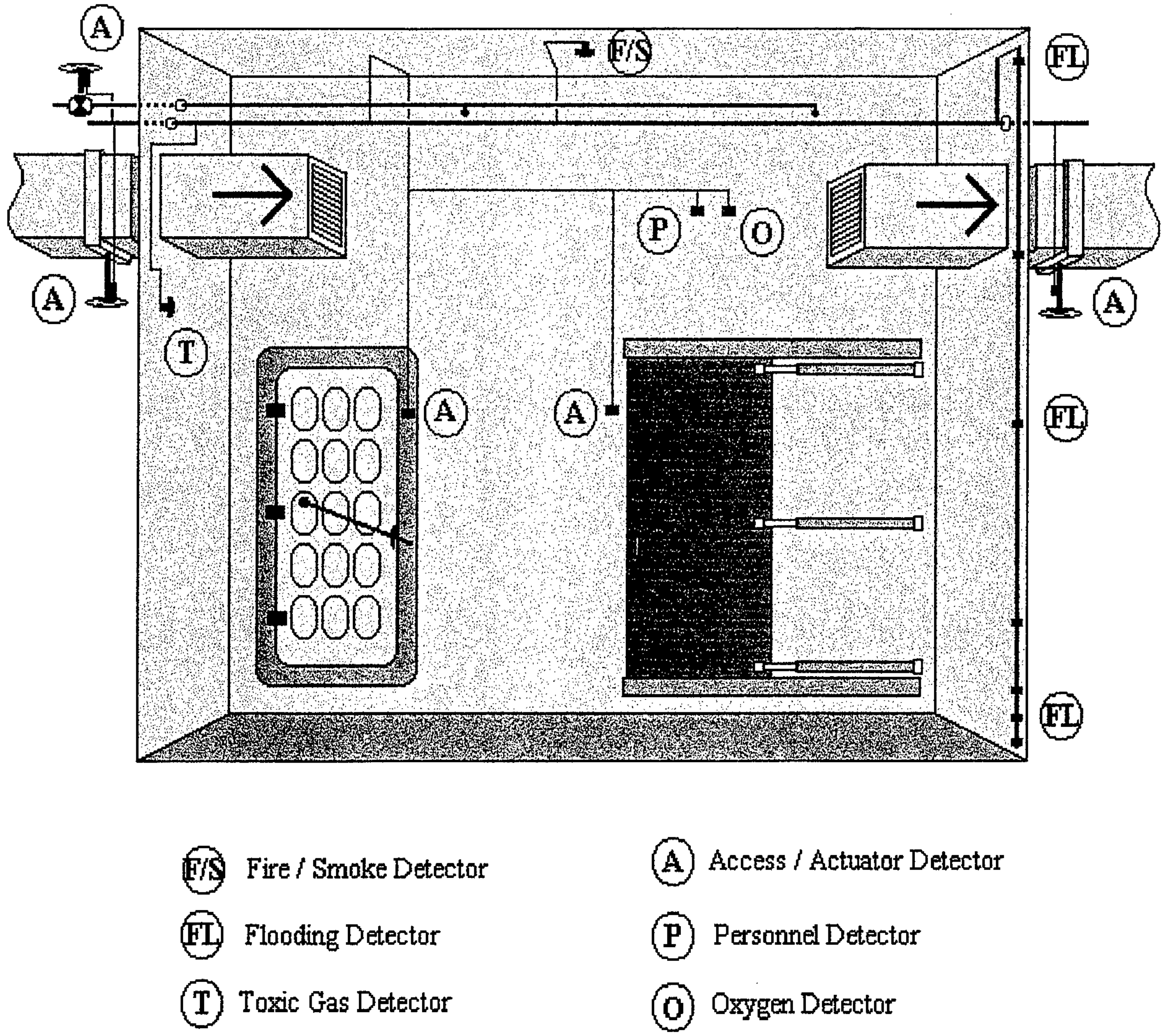

Figure 7 Typical Compartment Detector Arrangement

2. Data Network, Processing Centers, and Evaluation Tools

All sensors will be connected to a data network allowing the various processing centers to access the information. The processing centers in turn pass the information to the control centers for display and decision making. Multiple interconnected data networks are strategically routed throughout the ship. The redundant networks enhance the survivability of the system. All data networks will carry the same information, providing backup in the event of loss of a network. Each single network is capable of

handling the entire system requirements. The recommended data network would be a Thin Ethernet based upon the report "Ethernet Options for the EX-USS Shadwell" by David Tate and Dr. Frederick Williams of the Naval Research Lab. [Ref. 5]

Multiple distributed processing centers are located throughout the ship, with one center per zone. Each processing center is a hardened PC capable of independently supporting the system. Processing centers send information to the control centers, pass the information to evaluation tools, or initiate action based upon the sensor alarms.

Software programs such as Flooding Casualty Control Software (FCCS) will be included to calculate stability information. Other programs will provide information such as Material Safety Data Sheets (MSDS), Compartment Check-off lists (CCOLs), and compartment isolation procedures. These programs will provide the information automatically or when requested by an operator.

Pre-programmed sequences of actions will respond to the specific damage situations. These actions include information to prevent or slow the progression of damage. Ventilation settings, vital reroutes, preemptive DC settings and compartment access closures are controlled by these sequences. For example; in the event of a smoke alarm, the sequence could include information to secure the ventilation, start a fire pump and isolate the compartment. Actual extent of actions would have to be developed for each ship class based upon expert knowledge and current policy. The use of preprogrammed actions will be developed for each compartment and type of damage.

The network, distribution centers, and control consoles would have to be installed and the following summary is provided.

3. Control Station Display and Interface

Control stations will be located at the main watch stations including the Bridge, CIC, Damage Control Central and Engineering Control. All control stations will have full control and display capabilities. However, they do not have processing capability and therefore loss of a control station does not affect the system. Watchstanders will be able

to monitor the alarms and sequence of events that follow. Colorful graphical displays will provide easy-to-understand plots of the damage. This representation allows the control stations to make faster, better informed decisions in relation to their areas of control. Damage control plotting would be automatically performed from the known sensor information. Actions performed by damage control personnel could be added manually to the display at any control station. On scene personnel would have wireless hand held input/output into the ADCS.

Control stations can allow the system to act automatically or in a manual mode. In the automatic mode all preprogrammed events will be carried out without crew member involvement. In manual mode, the system would prompt a watchstander with the suggested action but would wait for the approval before carrying out the action.

4. Isolation System

The first reaction to any reported damage will be to isolate the damaged compartment to control or limit the spread of the damage. Remote closure of main personnel accesses will be controlled through the use of hydraulically and pneumatically operated watertight doors and hatches. Ventilation will be controlled by remote watertight actuators and fan settings. By concentrating on these main closures, damage is restricted to the smallest area possible. The ventilation closures may be kept open to facilitate certain procedures. The various arrangements will allow compartment de-smoking or the establishment of a buffer zone.

The automatic watertight doors and hatches will be located on the damage control deck and below. The watertight closures are located primarily for control of flooding. Automatic watertight hatches will prevent the vertical rise of damage, while, hydraulic doors will prevent horizontal damage progression. These automatic closures can be controlled remotely by the ADCS, allowing material condition to be set remotely and quickly. The watertight doors can, in emergency, be forced shut even in flooding situations. Required secondary escape scuttles will be still be available for egress. The

scuttles are normally closed, but will be monitored to assess closure. Personnel will be responsible for these closures.

5. Reactive System

The reactive system provides an offensive action against damage. Active damage control measures will be required to keep the damage contained and from progressing. Fire extinguishing methods include the use of a ship-wide water mist sprinkler system, AFFF flooding, and carbon dioxide flooding.

The water mist sprinkler system will be installed to combat fires. Water mist has been tested and successfully extinguished Class A, B and C fires; however, water mist is not intended as a total extinguishment agent. Small or smoldering fires may require additional extinguishment from damage control personnel. Water mist, however, can be used to keep the fire contained until DC personnel can arrive. Water mist is an excellent choice aboard ship and as a halon alternative.

The water mist system is comprised of 3.1 gpm sprinkler heads connected to a pressurized freshwater sprinkler main. A 300 gallon fresh water tank provides the immediate water requirements. Back up fresh water will be provided from the water tanks. Emergency water can be supplied from the fire main. The system will be pressurized to approximently 100 psi by an independent pump or hydropneumatic tank. Fresh water (especially evaporated and de-ionized water) is preferred over salt water because of reduced clean up concerns and it is less damaging to electrical systems.

Although individual compartment sprinkling is possible, it would require approximently 138 remotely operated valves and a drastically more intricate sprinkler design. The water mist sprinklers are instead grouped by watertight zones, requiring only 28 remote valves.

Specialized spaces will be protected by independent extinguishing agents, such as CO2 flooding for the paint locker and computer rooms. Machinery spaces will be protected by AFFF flooding and sprinklers. The AFFF systems will be conventional AFFF

overhead sprinklers and bilge flooding systems. Combinations of the water mist sprinklers and AFFF sprinklers will be used to combat fuel fires.

Flooding situations(water or other liquids) will be addressed by isolating the compartment and by the use of installed drainage. Small amounts of flooding are treated as bilge water and automatically pumped to the oily waste tanks. Large amounts of flooding water are shifted directly overboard.

Smoke, toxic gas, or oxygen deficiency will be handled by controlling ventilation arrangements. Proper ventilation control, positive or negative, can be applied zone by zone to properly vent the compartment. Smoke boundaries and positive pressure buffer zones will be automatically set by the preprogrammed ventilation arrangement. A complete ventilation redesign, for the 270', will be required adding a zonal distribution supply and exhaust system. This was considered outside the scope of this thesis.

The entire system as described would be required to make up a fully functioning ADCS. It will manage and control all of the damage control sensors and actuators, providing the information displays to the control stations. All plotting and information transfer will be performed electronically and transmitted to all control stations automatically in real time. The ADCS would plot without personnel involved. Other actions performed by damage control personnel are easily plotted manually, by clicking a mouse on the appropriate areas. ADCS would handle many of the typical damage control functions automatically, easing the requirements on the damage control personnel. Smaller specialized groups of damage control personnel would address situations not controlled by the ADCS.

VI. COMPARISON

The information presented in the previous chapters presents the possible technology and systems available for integration into an Automated Damage Control System. Systems, such as the one described, could be installed on future Coast Guard Cutters and have a favorable impact upon the required crew size. However, other factors have to addressed to gain perspective of the whole installation. Discussions of the differences between the baseline vessel and the new design will be covered in this chapter.

A. BASELINE VESSEL

The baseline vessel used in this study was the Coast Guard 270' WMEC cutter. This is a 1860 ton vessel is the second largest cutter in the Coast Guard Fleet. This cutter was built with the latest technology of the 70's and is the most automated coast guard vessel with the exception of the new buoy tenders currently under construction. This very capable cutter is able to perform all the required Coast Guard missions without assistance. It was selected as the baseline vessel because it was deemed to be a "good" Coast Guard platform and new cutter classes would likely be similar in function and size.

This cutter is equipped with "standard" cutter damage control equipment including a fire detection system, bilge alarm system, a single "trunk" firemain, an AFFF station and sprinklers, saltwater magazine sprinklers and paint locker CO2 flooding. Two repair lockers provide damage control support under the control of Damage Control Central. The damage control organization requires 35 (out of 100) crew members to operate to Coast Guard Standards. It should be noted that typical Coast Guard Manning levels are lower than standards set forth in NSTM 079 for Naval vessels. More information on the baseline vessel and its damage control systems is included in Appendix D. Figures 8-11 are provided depicting the existing systems on board the 270' Cutter.

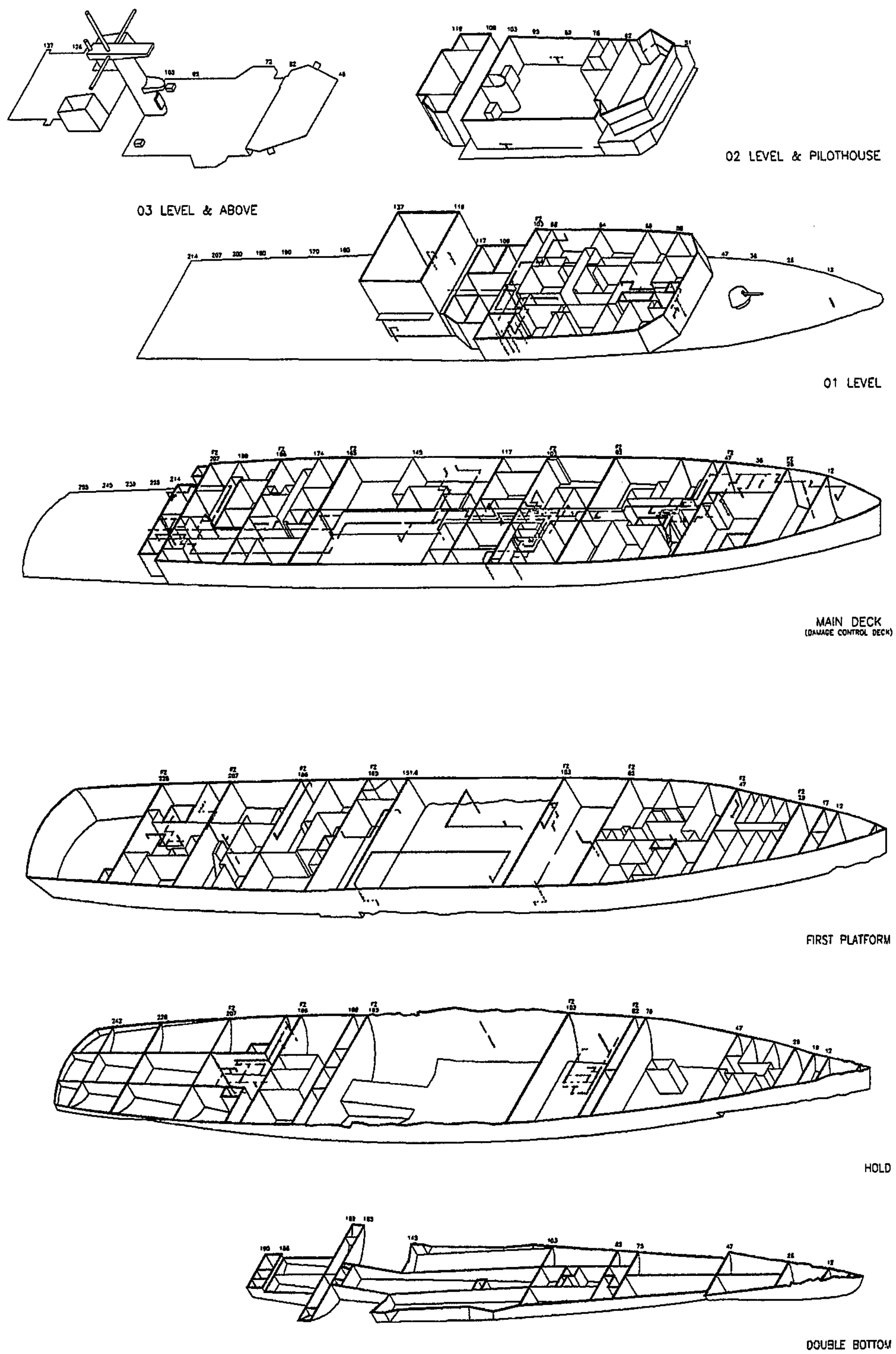

Figure 8 Baseline 270' Firemain, AFFF, and Sprinklers

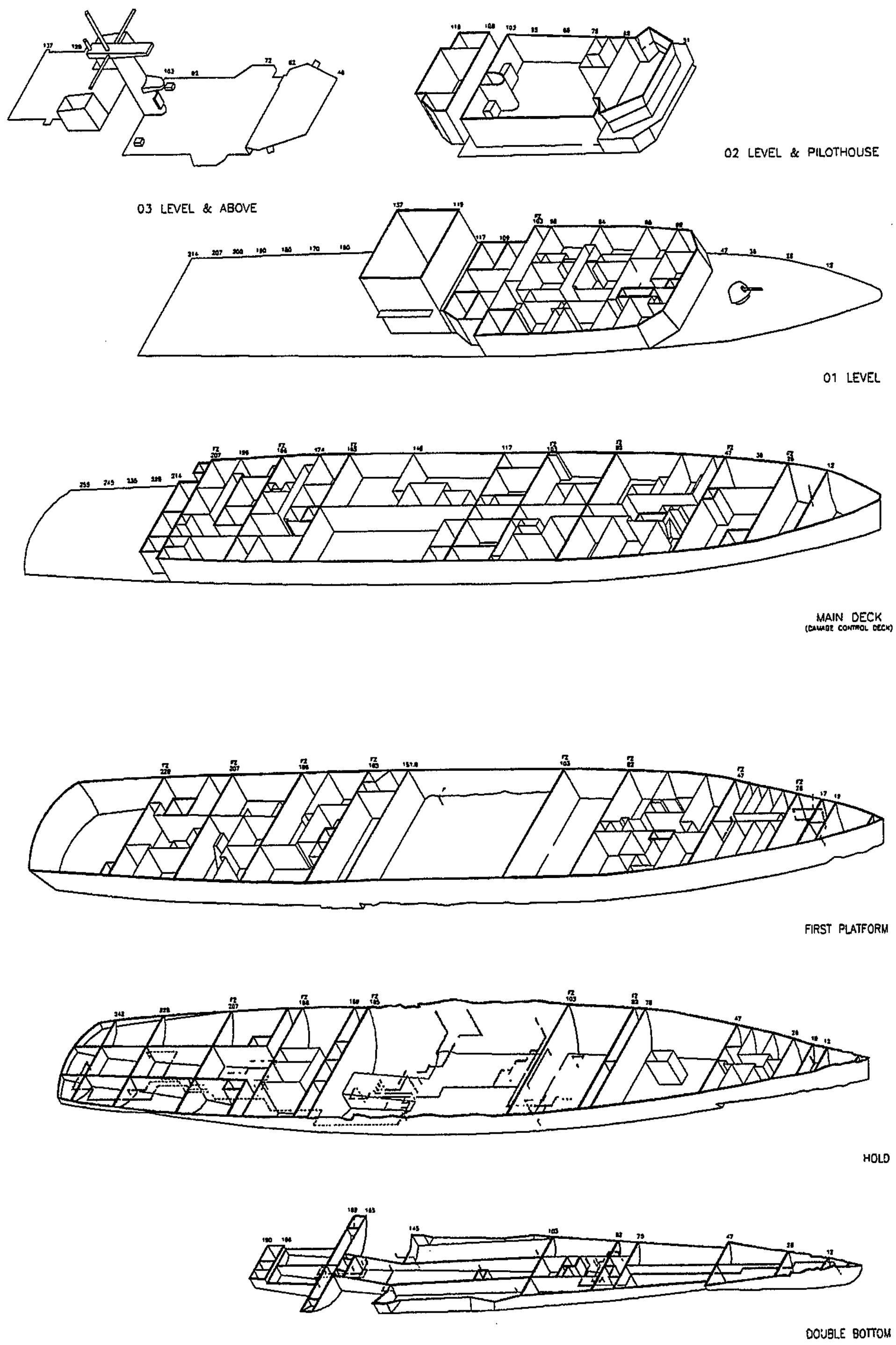

Figure 9 Baseline 270' Installed Drainage

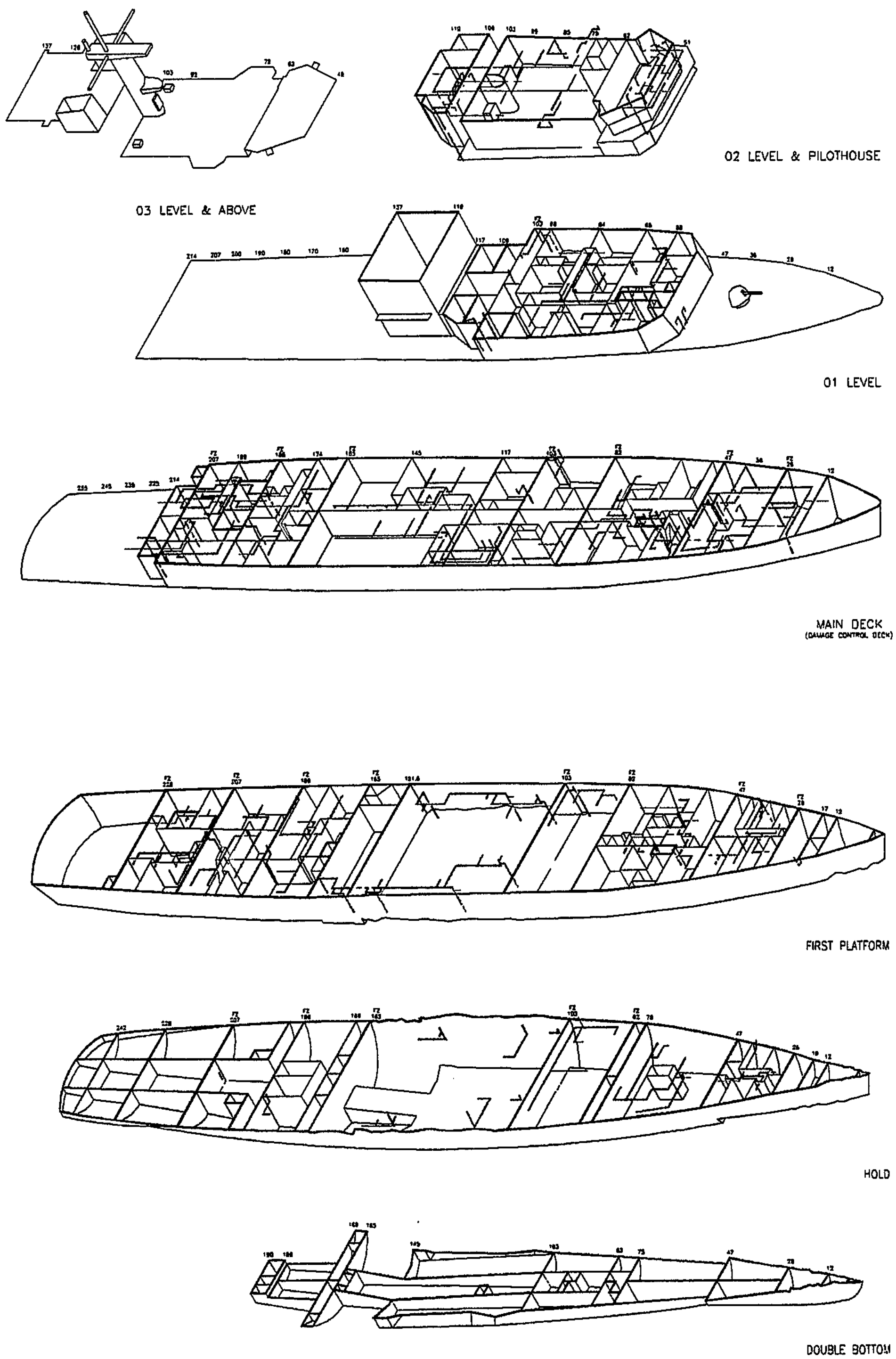

Figure 10 Baseline 270' Supply Ventilation

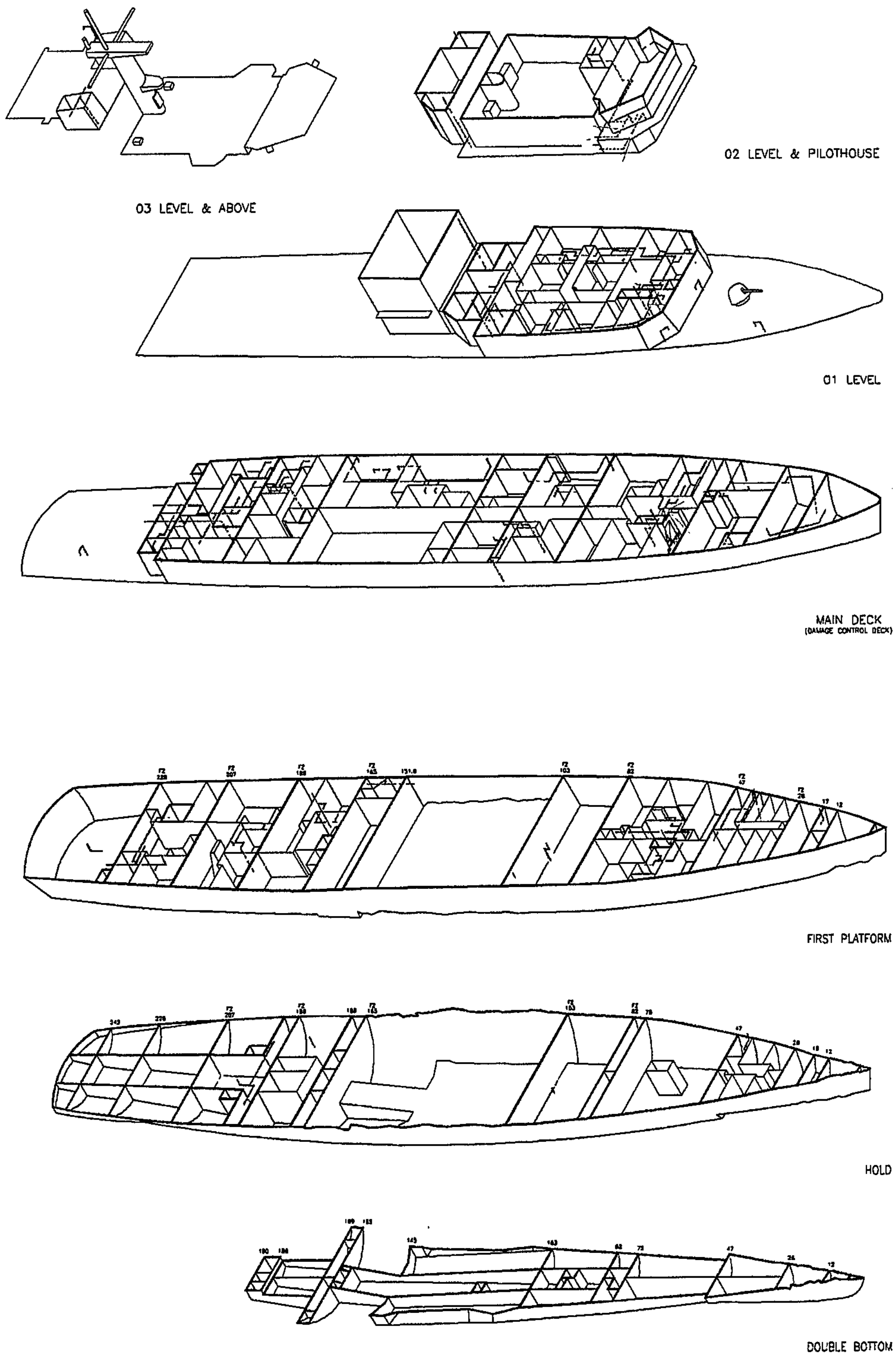

Figure 11 Baseline 270' Exhaust Ventilation

B. NEW DESIGN IMPACTS

The new damage control capabilities discussed in the previous chapter have to be added to the baseline vessel. The "engineering" impacts of the Automated Damage Control System, including added weight, volume, cost, and electrical load, are summarized in the following sections. Spreadsheets used in calculating the impacts are included in Appendix D and summarized portions are provided in this chapter. Manning impacts will also be discussed separately in this chapter.

The new sensor network requires the removal of the existing fire detection system to be replaced by the new detector system described in Chapter III.

Item	Weight	Volume	Electrical	Cost
Sensor Network (444 Sensors)	+ 1.3 Lts	minimal	16 Amp at 115 V (1.8 KVA)	≅ $72 K
Existing system Removal	- 0.12 Lts	minimal	minimal	n/a

Table 6 Detector Network Impacts

The impacts of installing the data network, processing centers, the four control consoles and supporting equipment are summarized in Table 7. The removal of the existing engineering consoles is taken as part of the damage control evaluation because of the need to upgrade all the control systems in to install an ADCS. The ADCS control station can be used to display engineering control station data or functions. All evaluation software tools are included in processing centers. Software costs are estimated at $150,000 per ship in a multi-ship contract. Single vessel installation costs would be substantially higher.

Item	Weight	Volume	Electrical	Cost
Control Stations	+ .54 Lts	+ 96 ft^3	36 Amps at 115 V (4.1 KVA)	≅ $40 K
Network Cable	+ .25 Lts	minimal	n/a	≅ $10 K
Data Processing	+ .40 Lts	+ 96 ft^3	36 Amps at 115 V (4.1 KVA)	≅ $48 K
Existing system Removal	- 2.5 Lts	-48 ft^3	n/a	n/a

Table 7 Impacts of Processing and Control Stations

Isolation is performed by adding 26 hydraulic doors and hatches. The installation of these doors and hatches effectively breaks the vessel into 29 remotely controlled watertight compartments. Thirty four remote ventilation closures are required to isolate the ventilation system to these compartments. Table 8 summarizes theses details.

Item	Weight	Volume	Electrical	Cost
Hydraulic Doors and Hatches (26)	+ 3.01 Lts	+ 108 ft^3	405 Amps at 115 V (47 KVA)	≅ $110 K
Ventilation Valves (34)	+ 0.76 Lts	minimal	102 Amps at 115 V (12 KVA)	≅ $17 K

Table 8 Impacts of the Isolation System

The reactive system adds 14 remotely operated valves to the existing installed drainage systems to provide complete automated drainage capability. A new water mist sprinkler system, with 28 remotely operated valves, provides complete ship coverage. Table 9 list the details and Figure 12 provides the layout of the sprinkler system.

Item	Weight	Volume	Electrical	Cost
Water mist System	+ 2.43 Lts + 2.84 Lts (w/ water)	minimal	102 Amps at 115 V (12 KVA)	≅ $25 K
Drainage System Valves (28)	+ .63 Lts	minimal	102 Amps at 115 V (12 KVA)84	≅ $14 K

Table 9 Impacts of the Reactive System

The additions described in this chapter add a total of 7.11 long tons to the vessel, add 252 ft^3 of equipment, require and additional 800 Amps of electrical load at 115 Volts. The entire system would cost approximently $490,000. These impacts in displacement, volume, electrical load and cost are associated with the physical installation of the systems to this ship. They do not take into effect the impacts of the removal of the associated crew members and effects. This data is considered applicable to installation as a new build or as retro-fit in an complete vessel overhaul much like the 378' FRAM and the 210' MMA.

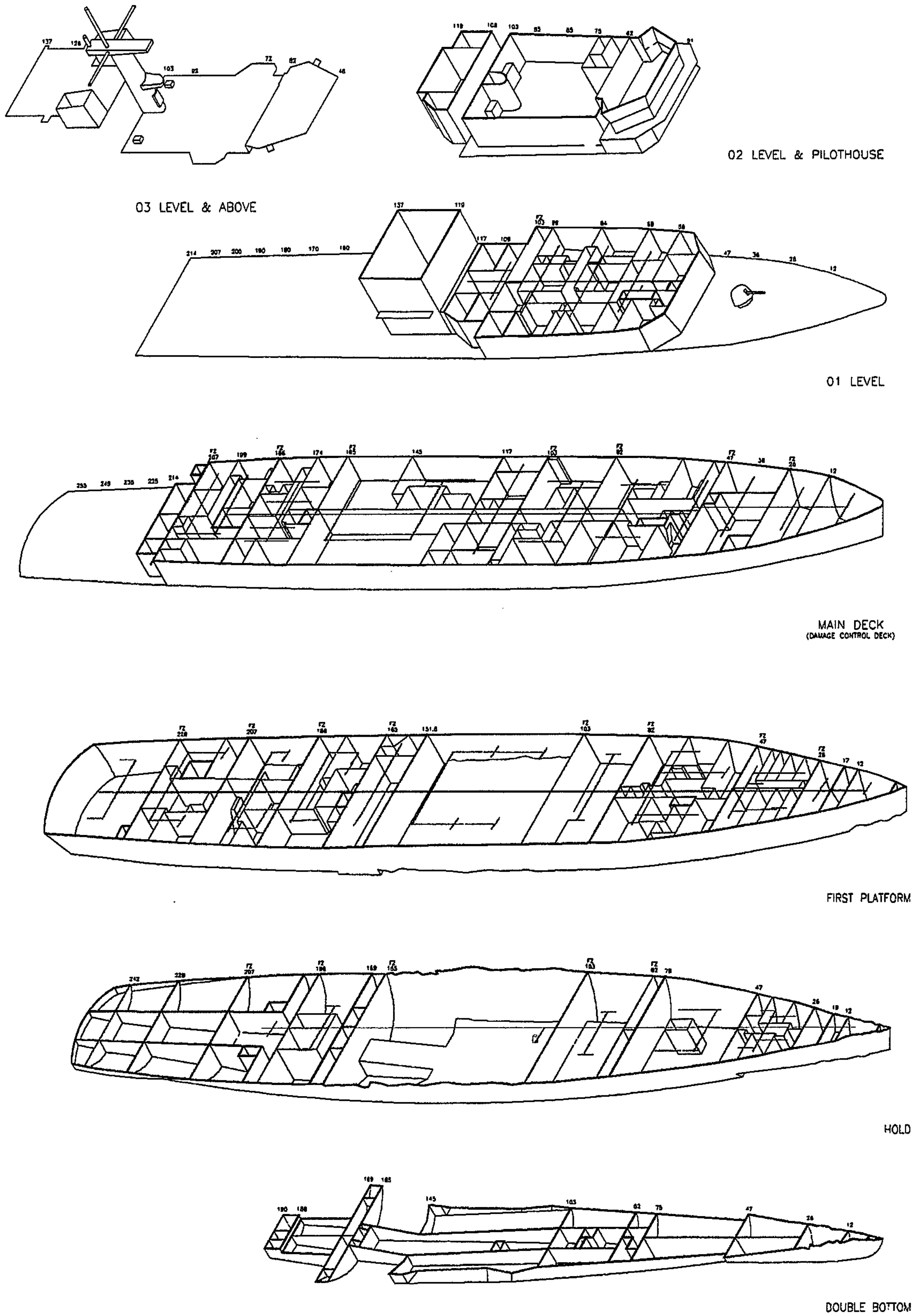

Figure 12 New Design 270' Water Mist System

C. MANNING CONSIDERATIONS

This section is not a detailed evaluation of the manning levels onboard Coast Guard vessels but is only the authors' educated opinion with respect to the possible savings associated with an Automated Damage Control System.

The levels of current manning could certainly be reduced with the proper installation of an Automated Damage Control System. It is conceivable that virtually all damage, once detected by the detection system will be automatically isolated and contained. New detection systems are more capable and faster than the earlier detection systems, providing more accurate, pinpoint, detection of damage. Investigators, charged with this responsibility, can be reassigned to other duties. The automatic isolation of the compartment also eliminates several persons that are tasked with setting and holding the boundaries. It would be possible to remove up to 8 persons from the investigators and boundary holders.

The reactive system provides the application of the extinguishment agent, negating the need to send personnel into dangerous situations. This system can also replace at least one of the two attack teams resulting is a savings of 6 persons. Attack teams may not have to actively enter damaged spaces if the extinguishment agents can be applied by remote application and the agent is capable of extinguishment, as with the water mist system.

Three phone talkers are currently required in Damage Control central and the two repair lockers, not to mention the phone talkers in CIC, gun mount and bridge. The graphical display capability of the ADCS system would eliminate the need for these persons, saving 3 persons from the damage control organization and two from the other control stations.

It is of authors' opinion that at least 17 persons could be removed from the 270' damage control organization.

Additionally, if this type of system were considered as part of the initial design, the reduction if 17 persons from the crew would have a substantial impact on vessel size.

There is a well used "thumb-rule" for vessel design that provides 4 lts and 437 ft3 per crew member, providing a savings of 68 lts to the vessel displacement and 7400 ft3 to the volume.

Annual operating cost would be drastically reduced providing actual savings by having less crew. A recent study, [Ref. 15], by the navy found the average cost of a "sailor" to be $55 K per year. A reduction of 9 personnel recoups the initial cost in the first year. It is realized that regardless of the savings associated with automation we must still continue to carry enough personnel to carry out our missions safely and effectively.

V. CONCLUSIONS AND RECOMMENDATIONS

The objectives of this study have been successfully met. The technology assessment provided valuable information about currently available damage control capabilities. It is now realized that currently available systems can provide vast improvements to the way damage control is performed. The information was used to formulate a conceptual design to be compared to the baseline. The parameters impacted were calculated and discussed.

A. CONCLUSIONS

Based upon the conceptual design, discussed in Chapter III, and without accounting for any removals of personnel, the following statements can be made about the impacts of an Automated Damage Control Systems.

1. added weight will be minimal
2. added volume will minimal
3. electrical load impact will be moderate
4. cost, approximently $0.5 M/ship, will be a major consideration for Coast Guard Vessels

Accounting for the removal of the crew made possible by the Automated Damage Control System the following will apply.

1. a sizable reduction in weight may be achieved
2. a reduction in volume may be achieved
3. electrical load impact will be moderate
4. substantial cost savings can be realized

B. RECOMMENDATIONS

This was the first attempt to quantify impacts in this area and because of time limitations some desirable areas were not as thoroughly explored as others. The following recommendations are made for pursuit of future research in this area.

1. Evaluate similar installations on other vessels to determine if any trends become apparent.

2. Perform a more in-depth study of the automation process leading to the development of well defined design criteria for use by future ship designers.

3. Survey on going R&D research to identify how emerging technologies could further bolster the effectiveness of an Automated Damage Control System.

4. Follow up on future installations of Automated Damage Control System (i.e. LPD-17) to determine if the promise envisioned in this thesis is actually realized.

APPENDIX A. SENSOR AND DETECTOR OPERATION, THEORY AND PARAMETERS

The following is a brief description of each type of detector mentioned in Chapter IV. This section is provided as background information for the reader. Additional information can be obtained from two separate reports titled, "Alternative Approaches to Integrated Damage Control Systems (IDCS) for USCG Vessels" and "Evaluation of Non-Developmental Items (NDI) sensors" both by John J. McMullen Associates, INC. [Ref. 2 & 3]

A. SMOKE DETECTORS

Photoelectric smoke sensors operate by projecting a beam of light across a sensing chamber. A photosensitive receiver detects changes in the projected light pattern caused by smoke particles within the chamber. These detectors provide good response to smoke with larger particles. However, they are subject to false alarms from other airborne particulates.

Optical detectors (including fiber optics) are based upon the photoelectric principle, except the beam is not confined to a sensing chamber and may be projected across open areas. These detectors can monitor areas up to 25 meters across, and areas subjected to high air flow rates.

An ionization detector uses an extremely small quantity of radioactive material to make the air in the detector chamber conduct electricity. Smoke from a fire interferes with the electrical current and triggers the alarm. Smaller particles are detectable, as compared to the photoelectric sensor, providing higher sensitivity in critical compartments. These detectors can also be prone to false alarms from airborne particulate matter.

Electrostatic detectors operate by detecting naturally charged particles across a set of electrodes. The principle of operation is the same as the ionization detectors without

the need for a radiation source, as with an ionization detector. These detectors are not as sensitive as ionization detectors and do not alarm with "nuisance" smoke, such as burnt toast. These detectors generally require smoke from a developed fire to trigger an alarm.

B. FIRE/FLAME DETECTORS

Infrared and ultraviolet detectors operate on the ability to distinguish the respective radiation wavelengths that are only given off during a fire. These optical sensors are capable of monitoring large open areas by a single sensor. Infrared sensors can be subject to false alarms by such things as electrical arcs, whereas ultraviolet sensors are virtually foolproof. Certain infrared sensors can also be used to monitor temperatures by annualizing the returned radiation spectrum.

Ultraviolet (UV) optical flame detectors are commonly used throughout the world today in many industrial applications. They provide quick response to virtually all fires, and have few naturally occurring false alarm sources. They are a good choice for many applications, but subject to false alarms from arc welding or lighting. UV detectors typically respond to a 1 square foot gasoline fire at a distance of 50 feet. Optical integrity features allow remote testing of all optical surfaces to ensure that no obstructing residue is present and that all electronic circuitry is operating correctly. Thresholds can be preset to determine when cleaning is required, reducing maintenance procedures. This testing can occur automatically or be manually initiated from the control panel.

Infrared (IR) detectors analyze specific frequencies given off during a flame flickering. These detectors provide reliable alarms to fires, yet can ignore things like arc welding, nuclear radiation and x-rays. They respond to a fire even while arc welding is being performed, making them ideal for applications such as welding shops and areas. Infrared detectors are less affected by optical contamination such as dirt, oil and smoke, than other detectors, making them one of the best choices for adverse conditions.

IR detectors typically respond to hydrocarbon fires within 3 to 5 seconds and to an intense "flash" type fire in less than 50 milliseconds, while still discerning slower

starting fires from other radiation sources in the environment. IR detectors typically respond to a 1 square foot gasoline fire at a distance of 65 feet. Optical integrity features are available on the IR detectors as well. IR detectors are ideal detectors in areas subject to high air flows and heavy concentrations of airborne particulates.

Ultraviolet/infrared (UV/IR) combination flame detectors have a UV and an IR sensor mounted side by side. Both sensors are required to respond before a fire alarm is given. This "and gate" system makes them very resistant to false alarms including welding, x-rays, lightning, artificial lighting and interrupted hot body radiation, because while there are sources in the environment other than fire that will cause the UV or IR sensors to false alarm, the sensors have virtually none of these sources in common. UV/IR detectors typically respond to a hydrocarbon fire in 1 to 5 seconds. UV/IR detectors typically respond to a 1 square foot gasoline fire at 50 feet, a 4 square foot JP4 fuel fire at 100 feet within five seconds and a 100 square foot JP4 fuel fire at 150 feet within five seconds

C. HEAT DETECTORS

Heat detectors come in different types including spot detectors and line detectors. Spot detectors sense temperature at a specific location. Line detectors consist of a cable run where temperatures can be detected at a point along the cable, within a certain distance, typically 1.5 meters. Heat detectors work on four basic principles as follows:

Fixed temperature sensors alarm when temperature reaches a fixed point. Fixed temperature heat detectors are suited to alarm in the presence of slowly rising temperatures. Typically a bimetallic disc deflects when temperature reaches a predetermined value. The disc deflection causes a push-rod to close the internal contact resulting in an alarm condition. The bimetallic disc returns to its original shape when the heat subsides causing the internal contacts to return to their normally open position and a normal standby condition is restored. Typical threshold values are 135 or 190 degrees Fahrenheit , although other temperatures can be accommodated. Fixed temperature heat

detectors are suited for installation where high heat output fires are expected or in areas where ambient conditions will not allow use of other detection methods.

Rate of rise sensors alarm when rate of temperature increase exceeds a predetermined value. Rate-of-rise detection detectors often utilized thermistor sensors to monitor an ambient temperature change of 15 degree Fahrenheit per minute. The thermistor sensor provides a good response to rapid increases in temperature. It is common practice to have fixed rate sensors in combination with rate of rise sensors, providing good all round heat protection.

Thermoelectric effect sensors detect a change in electric resistance in response to an increase in temperature. These sensors are typically "hot wire" anemometers used for sensing temperature changes in fluid flows, including ventilation ducts. Changes in resistance are detected and correspond to a change in the fluid temperature. Temperature change of 1° F are possible.

Fiber optical heat detection is possible by use of monitoring the light scattering of light down the fiber optic is proportional to the temperature sensed along the cable. Detection of temperature changes of 0.1° C along the cable, are possible. Location of the heat detection can be made within 1.5 meter distances along the cable.

D. THERMAL DETECTION

Thermal imaging, and video fire detection techniques have been developed which compare previous images to changing images, detecting smoke and fire. Thermal imaging techniques, relying on infrared radiation, can detect temperature differences in the range of 1° C. Video cameras combined with digital monitoring can utilize these techniques to monitor previously installed closed circuit television cameras. These camera based systems can also double as back up visual remote monitoring of unmanned spaces.

Thermal infrared (TIR) sensing exploits the fact that everything above absolute zero (-459F) emits radiation in the infrared range of the electromagnetic spectrum. How much energy is radiated, and at which wavelengths, depends on the emissivity of the surface and on its temperature. Thermal infrared sensors record differences in the received

infrared radiation from various objects. Since these differences are often considerable, an infrared image can exhibit a wide range of contrasts.

Infrared energy is recorded in two ways. The first is with a radiometer, a device that records the radiation received and compares it to a fixed or known standard. The other recording device is an infrared scanner that uses a system of mirrors that rotate, or oscillate, and focus the incoming radiation on a detector. The infrared energy striking the detector creates an electrical charge that can be amplified and recorded on tape or film. With this kind of system it is possible to get a picture of the thermal environment that we cannot experience with our normal human sensors. The ability to record variations in infrared radiation has tremendous application in extending our observation of many types of phenomena in which minor temperature variations may be extremely significant in understanding our environment. For example, potential safety problems can be spotted by monitoring the temperature of electrical panels indicating shorting equipment.

E. LIQUID LEVEL DETECTORS

Typical flooding detectors are open/closed 'dry' contact type switches operating by a float mechanism. A number of these sensors can be mounted at various heights within a tank or compartment to determine the liquid level. These switches are either on or off, and the level of desired accuracy dictates the number of sensors. "Wet" type contact switches use the fluid level to complete an electrical circuit and provide the alarm. These sensors are not as desirable as the dry contact switches.

Continuous reading tank level sensors are available and operate by a detecting a resistance float sensor along a shaft, providing readings accurate to within one-half inch. Normal tank levels are typically monitored by these sensors. These continuous level sensors can also monitor for excessive liquid loss indicating a damage situation, or provide unmanned filling operations.

The open/closed contact switches can also be utilized for detecting actuator and access status. Fiber optical sensors have also been developed to provide this detection.

F. TOXIC GAS SENSORS

Infrared sensors have been developed to detect several toxic gasses. The infrared portion of the spectrum is one of the most useful for identifying a substance by detection which specific wavelengths are absorbed. Every material reflects or absorbs infrared radiation in specific patterns, allowing determination of each substance by comparison to a known standard. This detection capability has been developed into individual sensors of specific gasses.

Other gas sensors rely on the ability of a chemical cartridge to be chemically reactive with specific hazard. These sensors use consumable sensing elements and have 12 or 24 month service lives in normal conditions. Self diagnostics are also provide warning of an expended element.

Fuel cell sensors are miniaturized fuel cells which react to low (parts per million) concentrations of gas. Fuel cells are electric batteries which consume gas from outside rather than solid/liquid materials inside them. (Their original application was in space vehicles where hydrogen is consumed to provide electrical power.) They consume minute amounts of gas. The electrochemical reactions produce current (uA) which is linearly proportional to the concentration of gas in air. In theory, because fuel cell sensors consume no internal ingredients, they should have an infinite life. In practice they last 3 or 4 years.

Galvanic electrochemical sensors are not fuel cells because electrodes or electrolyte are used up. The metal is gradually consumed and this governs the sensor's life. Ammonia and hydrogen cyanide are measured by consumable or galvanic sensors. The life of these sensors is governed by the amount of gas which they absorb so their life can be shortened when exposed to continuous high levels of gas.

The table below gives a brief summary of sensor types. The gas type links lead to pages discussing the most suitable sensor types for a given application.

Sensor type	Detectable gases	Usable range	Pro's	Con's
Electro-chemical	Toxics, oxygen	ppm levels	Low Power, accurate, repeatable	3 year lifetime slightly lower at high temperatures; some types are cross-sensitive
Pellistor	Flammables	LEL levels	Generally good in all ways; portable	Can be damaged by high levels of H2S, but poison resistant types are available
Infrared	Flammables and CO2	0.1 (or less) - 100% by volume	Fail safe; generally excellent	Expensive (but getting cheaper); non-portable
Semiconductor	Many, at ppm levels ('broad range sensor')	ppm levels	Sensitive to range of gases	Cross-sensitivity; low resolution (bad zero drift); respond to humidity; require stable ambient conditions
Sulphistor	H2S	ppm levels	Long lifetime, robust	Non portable
Thermal Conductivity	Many, at % levels, including binary mixtures	% levels	20 year life (at least); stable; can detect inert gases	Only appropriate for certain gases

Table 10 Comparison of Various Detector Technologies [Ref. 14]

Shipboard smoke and fire detectors and systems have been commercially available for more than 10 years. Bilge and tank level sensor are also common. The Coast Guard already utilizes these systems onboard its cutters and has approved several of these systems for use on merchant vessels. This technology is proven and reliable. New advances in detector technology improve upon previous generations of detection. New capabilities include the ability to distinguish smoke characteristics in determining fire

classifications (white, gray, black). Toxic gasses or oxygen levels can also be monitored remotely. New detectors may also require multiple sensor activation to initiate an alarm, thereby reducing the number of false alarms. (smoke detectors may require a positive ionization and carbon monoxide identification before sounding the alarm).

APPENDIX B. INFORMATION DISPLAY SYSTEMS

Autronica Marine is one of the industry leaders and a major supplier of fixed fire detection systems to many merchant and foreign naval vessels. These systems are capable of handling over 1500 individual detectors and graphically displaying the information as well. Information exporting to other systems is possible through a data output module. A sample graphic from Autronica's AutoMaster 5000 is shown depicting compartment by compartment detection capability. The graphic display quickly and efficiently displays all known information to the control centers keeping everyone properly informed. Flooding, toxic gasses, fire door status, and damage control equipment status can also be displayed.

The Eagle 2000 monitors individual fire and gas detection points or even separate systems and integrates them into a single safety network. Eagle technology provides fault tolerant wiring and allows access to both present and historical data from a single control room location as well as from remote operator interface stations. In this way, important information is always available at your fingertips and full integrity of the safety system is never in doubt.

The basic Eagle 2000 system consists of a number of intelligent detection nodes and a gateway on a communication loop that can interface with a variety of host devices. The host device can be a Windows based PC or Macintosh, an approved fire panel, or one of a variety of DCS and PLC systems. Each detector on the network constitutes a node and has its own communication module. The communication module digitizes the detector signal for input to the gateway, provides calibration capabilities, and stores alarm and calibration data for the detector. The detector can be any device that is capable of generating a 4 to 20 ma output signal or has a digital output (switch or relay contact). The Eagle relay module can add both zoning and voting capabilities to the system. These highly versatile devices activate a self-contained relay in response to user selectable criteria for output actuation. The communication network is constructed as a loop that starts and ends at the gateway. A single network can have up to 250 nodes, with up to 10,000 meters of wire and up to four gateways. Specialized software can support up to

four separate networks. The entire interface is graphic in nature with no cumbersome keyboard commands to learn. Onscreen point and click icons allow convenient navigation through the application for easy access to various features

The US Navy has developed is own detection system. the Two Wire Automatic Remote Sensing and Evaluation System (TWARSES). This system was designed by an internal navy development in use on the EX USS Decatur DDG31 test ship. This vessel operates by remote control with out personnel on board. TWARSES is a stand alone modular system consisting of a network of sensors connected along a two wire line. The two wire line provides the sensor power as well as data transmission. The sensors are standard commercially available sensors monitored by a standard PC. The systems is notably inexpensive and easy to install or retire-fit. Graphic display of the information is shown on a Damage Control Plates. Radio link and telephone modem allow shore side monitoring of the ship, inport and underway, eliminating the need for shipboard watch standers. Multiple ships may be monitored by a single watch station. A separate data network would be required to pass information between control stations. More information can be obtained from the

The Damage Control System (DCS) by CAE Electronics Inc. has recently gained considerable attention by being installed on the USS Yorktown as part of the "Smart Ship" program. Other naval ship contracts including LPD-17 are under design, will include CAE's DCS systems. DCS can be a stand alone or an integrated part of the Standard Monitoring and Control System (SMCS). DCS monitors and controls all of the the damage control sensors and actuators. The damage control information is displayed on electronic damage control plates, much like the Autronica display. Firemain status or other damage control system information can be displayed as well. Sensors, processing units and control station are all on the same data network. Each control station is provided the same information in real time. See Figure 4 in Chapter II.

The important requirements of a detection system are the ability to monitor the spaces for the appropriate hazards and to display the information in a concise graphical presentation. Complete ship detection networks can detect damage in its infancy allow the

quickest response possible. The ability to send the information via radio link or telephone line may also be desirable by allow single inport duty sections to monitor several ships inport.

The level of automation and remote control tends to be the major factor in system cost. Remote actuators are generally quite expensive, and for each remote control available you must provide feedback to the user which increases the degree of monitoring. Automation must be implemented by system programmers which can be costly if the automation is extensive or complex.

A typical commercial levels of automation include, electrical plant reconfiguration, propulsion changeovers (on multi-shaft ships), auxiliary system standby control (fuel, lube, cooling water), automatic smoke control (HVAC),automatic fire suppression, automatic tank filling/shutoff.

In general, the commercial standards for unmanned engine rooms ships are applicable to a reduce manned Coast Guard Vessel., and provide a very good guide for a Coast Guard Vessel design (IMO, SOLAS, ABS, Lloyds, Det Norske Veritas). The Coast Guard vessel, is not a commercial vessel and not "technically" subject to standards other automation considerations can be considered.

New computer technology has drastically driven down the cost of computers and hardware to allow multiple backup computers to be installed adding redundancy and capability. Each 100 I/O sensors in the system require for one data-acquisition unit (Mini-Remote Terminal Unit). These are roughly 10" deep, 26" wide and 42" high and are designed for bulkhead mounting. The M-RTU requires about 75 watts @ 28 VDC but this does not include provision of power for actuators, which require and additional 150 watts. Each M-RTU weighs approximently 74 pounds.

Each control station console (there may be more than one per control station) operator station requires 1000 watts at 120 VAC. Two PC based consoles are available, a standing console used for the Damage Control in damage control lockers and a seated console used for all systems in the control rooms. A desktop unit is available for office use, such as in the engineering office. The standing console is roughly 6' tall, 30"wide

and 20" deep. and is designed for deck mounting with top steadying brackets. These consoles weigh approximately 175 pounds. The seated consoles are approximately 4" high, 30" wide and 48" deep and weigh approximately 250 pounds.

Normally all equipment is powered from uninterruptable power supplies, thus the 28 VDC for the MRTUs can be made available even is the ship has no 28 VDC distribution.

A hand held, wireless version is available to communicate with the main control stations. The damage control communicator is a wireless networked "hand-held" pen based computer that electronically transmits ship damage or onscene information instantly to the Damage Control Center or Repair Party Leaders. This system promises to replace the existing messages forms, which are hand carried throughout the ship. The existing process is a slow arduous and prone to hand copied error. The Damage Communicator reduces the necessary damage control staffing (no message carriers or plotters), eliminates copy error, allows multiple sites to read information, and provides all control stations and damage control personnel information in real time.

APPENDIX C. WATER MIST TECHNOLOGY INFORMATION

Water mist sprinkler systems are not new technology. The development of water mist sprinklers was developed in the early 1900's and testing performed on flammable liquid fires in the 1920's. An awareness of drop size, in relation to extinguishment capability, occurred in the early 50s with the development of the "standard" spray sprinkler. It was noted during testing that the smaller droplets provided a greater available surface area for cooling and heat absorption. However, other developments, of the time, caused the water mist sprinklers to be left behind in the expanse of finding better fire fighting agents. Halon replacement research, forced by environmental impacts of halon, have resulted in a return to water mist sprinklers. New water mist sprinkler systems are "fore front" in the halon alternative debate.

Water mist works on the principle of reduced water droplet size. Since heat absorption is a function of surface area, not volume, smaller droplets mean more surface area, resulting in faster heat absorption. The smaller droplets and cyclic system operation also aid in oxygen dilution around the fire area, helping extinguishment.

Fine water mists can be generated by intermediate pressures (75-190 psi) allowing the use of minimum wall thickness pipe. The same design philosophy and components found in traditional water sprinkler systems, such as pipe work design, pumps, fittings, and couplings can be directly applied providing inexpensive design and installation. Additional savings come from the fact that a minimum flow of just 3.1 gallons per minute is required from each nozzle at a maximum spacing of 6.6 ft. x 6.6 ft. This means smaller pipe diameters and less weight and cost.

Water mist systems are also safer for people and the environment. These systems only use potable or natural sea water, with no adverse side effects. Lower flow rates equate to less cleanup than traditional water sprinkler systems. Tests have shown that properly designed water mist systems can effectively extinguish a wide variety of exposed

and shielded Class B hydrocarbon pool, spray, and cascading pool fires. Test of incidental and combinations of Class A , B, and C fires have also been tested and extinguished.

A general reluctance to provide water protection of class "C" fires exists because of fears of conductivity. Water mist systems have been successfully tested on telecommunications switch gear equipment, consisting primarily of vertically-mounted circuit boards. Typically this equipment would be protected by Halon or Carbon Dioxide systems but testing was conducted to ascertain the water mist capabilities on electrical equipment. The tests found that maximum temperatures of the fire were reduced as well as reductions in smoke obstruction. Extinguishment was accomplished within two seconds, using less than one liter of water. The water mist proved to be less conductive than smoke encountered in the unsuppressed tests, and did not damage any electrical equipment within the switchgear module. Another study by the National Institute of Standards and Technology, showed that fresh water was not found to be a cause of the shorting of electrical equipment. Salt water, however was significantly more likely to be a potential problem.

Another application that has been directly affected by the phase out of halon is the fire protection of gas turbines. A special nozzle has been developed that mixes air and water at pressures of 60 to 90 PSI, to create a fine mist with very small droplet sizes. The test included pool fires, fuel spray fires, combination pool/spray fires, or smoldering insulation fires. The water mist system was discharged for 10 seconds, with immediate extinguishment observed in most cases. A second discharge of 10 seconds was necessary in some tests, to ensure extinguishment. The cycling of the system was found to provide additional mixing and aided in the extinguishment of the fire.

The recent flurry of activity surrounding water mist systems and the many successful research efforts with water mist are cause for encouragement and excitement. Successful application of water mist for several passenger vessels in Europe and approvals obtained by several maritime approving authorities demonstrates a portion of the future of shipboard water mist systems. In the United States, water mist primarily remains a research effort with exciting possibilities and potential to replace halon.

APPENDIX D. BASELINE 270' INFORMATION

The thirteen Coast Guard 270' Famous Class Cutters were built between 1979-1988. The first four A-Class Cutters were built at Tacoma Boat between 1979 and 1982. The other nine B-Class were built at Derecktor Shipyard between 1982 and 1988.

The 270' WMEC principal Characteristics are:

General Characteristics	
Length, Overall (LOA)	270'-0"
Length at Waterline (DWL)	255'-0"
Extension Forward of FP	11'-0"
Extension Aft of AP	4'-0"
Molded Beam (Maximum)	38'-0"
Molded Beam (DWL)	37'-9 3/8"
Mean Draft (DWL)	13'-0"
Freeboard at Bow to DWL	21'-8"
Freeboard at Stern to DWL	10'-6"
Displacement (DWL)	1645.95 Lts
Full Load Draft	13.85'
Full Load Displacement	1825.64 Lts
Frame Spacing	
Type	Longitudinal
Spacing	1'-0" throughout
Numbering	0 - 259
Main Engines	
Type	Diesel, 18 cylinder Turbo-charged
Number of Units	2
Manufacturer	Alco
Model	18-251F
Rated Speed	1025 RPM
Rated Power	3650 HP
Propellers	
Manufacturer	Tacoma Boat-Esher Wyss
Model	850
Number of Units	2
Type	Controllable Pitch
Number of Blades	4 per Hub
Diameter	9' -0"

Armament

76MM/62 Caliber, Mark 75 Gun	1	
50 Caliber Machine Guns	2	
5.125", Mark 137 SRBOC Launchers		2

Flooding Limits

2 Compartment Damage	All Cases
3 Compartment Damage	FWD FR 47, FR-12-82, FR 26-103
4 Compartment Damage	FWD FR 82

Hydrostatics

	Full Load	Min. Operating
Displacement (Lts)	1863.80	1767.50
Keel Draft at LCF (Ft)	14.04	13.59
Center of Gravity above Base(KG), (Ft)	16.95	17.15
LCG From Midships (+ Aft) (Ft)	4.0	6.95

The 270' WMEC currently only has an installed smoke and fire detection system, manufactured by Pyrotronics Corporation. The system consists of 50 detectors that monitor 16 zones and controlled by one master control panel. The current system requires 9 Amps at 115 Volts for power. Two back up batteries are provided for emergency backup power. Bilge alarms are located in the lowest spaces along the hull, providing an alarm to water in the bilge of these compartments.

The vessel has a single fire main that provides fire fighting water to hose stations throughout the vessel. AFFF stations provide sprinkling to the engineroom and JP-5 pump room, flight deck and hanger. The AFFF station operation can be operated remotely by push button. Water sprinkling is provide to the magazines to provide flooding capabilities. Additionally the paint locker is protected by a fixed CO2 flooding system. Figures (12-14) are provided as reference for the base line vessel.

Two damage control repair lockers and Damage Control Central are manned during emergency situations. Each repair locker has 16 persons assigned and DCC has 3 persons assigned (35 Total). The following table is a breakdown of this manning.

Damage Control Central (DCC)	**Repair II**	**Repair III**
Damage Control Assistant (1)	Locker Leader (1)	Locker Leader (1)
Plotter (1)	Onscene Leader (1)	Onscene Leader (1)
Phone Talker (1)	Team Leader (1)	Team Leader (1)
	One Attack team (4)	One Attack team (4)
	Investigators (2)	Investigators (2)
	Phone talker (1)	Phone talker (1)
	Messenger (1)	Messenger (1)
	Boundary men/Other (5)	Boundary men/Other (5)

Table 11 Standard Repair Locker Manning of a 270'

APPENDIX E. DESIGN CALCULATION SPREADSHEETS

A. REQUIRED SENSORS

Legend

Optical - Optical Smoke/Fire Detector
Sion - Smoke Ionization Detector
G - Combustible Gas Detector
T - Temperature Detector
Sump - Bilge Contact Alarm
Heat - Heat Detector
Exi - Explosion Proof Detector
H - Humidity Detector
N - Toxic Gas Sensor (PERC)
Tank - Continuos Reading Sensor

	Flooding	Qnty	Cost	Weight	Other	Qnty	Cost	Weight	Smoke	Qnty	Cost	Weight	Electrical	Total
Number	Sensors			(lb)	Sensors				Sensors				(mA)	Sensors
5-99-0-T									Optical	1	60	2	0.3	1
03-97-0-Q									Optical	1	60	2	0.3	1
02-45-0-Q									Optical	1	60	2	0.3	1
02-48-0-Q									Optical	2	120	4	0.6	2
02-63-0-C									Optical	4	240	8	1.2	4
02-63-2-L									Optical	1	60	2	0.3	1
02-72-2-L									Optical	1	60	2	0.3	1
02-73-1-Q									Optical	1	60	2	0.3	1
02-73-2-Q									Optical	1	60	2	0.3	1
02-96-0-M									Sion/exi	1	180	2	0.3	1
02-106-0-Q									Sion	1	180	2	0.3	1
02-106-1-Q									Optical	1	60	2	0.3	1
02-106-2-Q									Optical	1	60	2	0.3	1
01-47-1-L									Optical	1	60	2	0.3	1
01-47-2-L									Optical	1	100	2	0.3	1
01-47-3-L									Heat	1	100	2	0.3	1
01-47-4-L									Heat	1	100	2	0.3	1
01-47-5-L									Optical	1	60	2	0.3	1
01-52-0-L									Optical	1	60	2	0.3	1
01-52-1-A									Optical	1	60	2	0.3	1
01-58-2-L									Optical	1	60	2	0.3	1
01-61-1-Q									Optical	1	60	2	0.3	1
01-68-0-L									Optical	1	60	2	0.3	1
01-68-01-L									Optical	1	60	2	0.3	1
01-68-1-L									Optical	1	60	2	0.3	1
01-68-2-L									Heat	1	100	2	0.3	1
01-68-4-L									Optical	1	60	2	0.3	1
01-81-1-L									Heat	1	100	2	0.3	1
01-82-1-L									Optical	1	60	2	0.3	1
01-84-2-L									Optical	1	60	2	0.3	1
01-85-0-L									Optical	1	60	2	0.3	1
01-89-2-L									Heat	1	100	2	0.3	1
01-94-1-L									Optical	1	60	2	0.3	1
01-94-2-L														
01-95-1-Q									Sion	1	180	2	0.3	1
01-98-0-L									Optical	1	60	2	0.3	1
01-103-0-Q					G	1	100	2	Sion	1	180	2	0.6	2
01-103-1-Q									Optical	1	60	2	0.3	1
01-103-2-Q									Optical	1	60	2	0.3	1
01-109-1-Q									Optical	1	60	2	0.3	1
01-109-2-Q									Optical	1	60	2	0.3	1
01-117-0-Q									Optical	1	60	2	0.3	1
1-J-0-K					G	1	100	2	Sion/exi	2	360	4	0.9	3
1-12-0-Q									"Sion"	2	360	4	0.6	2
1-26-0-M					G,H,T,N	4	400	8	Sion/exi	2	360	4	1.8	6
1-26-1-C					G,H,T,N	4	400	8	Sion/exi	2	360	4	1.8	6
1-26-2-L									Optical	2	120	4	0.6	2
1-43-2-Q									"Sion"	1	180	2	0.3	1

1-47-0-L									Optical	2	120	4	0.6	2
1-47-1-Q									Optical	1	60	2	0.3	1
1-51-2-L									Heat	1	100	2	0.3	1
1-53-1-A									Optical	1	60	2	0.3	1
1-56-1-A									Optical	1	60	2	0.3	1
1-58-1-L									Optical	1	60	2	0.3	1
1-61-2-L									Optical	1	60	2	0.3	1
1-62-2-A									Optical	1	60	2	0.3	1
1-65-2-A									Optical	1	60	2	0.3	1
1-73-1-Q									Optical	1	60	2	0.3	1
1-82-1-L									Optical	1	60	2	0.3	1
1-82-2-A									Optical	1	60	2	0.3	1
1-82-3-Q									Optical	2	120	4	0.6	2
1-82-4-Q									"Sion"	2	360	4	0.6	2
1-90-2-Q									"Sion"	1	180	2	0.3	1
1-95-1-A									Optical	1	60	2	0.3	1
1-96-1-L									Optical	1	60	2	0.3	1
1-103-1-L									Optical	1	60	2	0.3	1
1-103-2-L									Optical	1	60	2	0.3	1
1-103-3-A									"Sion"	1	180	2	0.3	1
1-103-3-Q									"Sion"	1	180	2	0.3	1
1-103-4-A									"Sion"	1	180	2	0.3	1
1-103-4-Q									"Sion"	1	180	2	0.3	1
1-113-2-L									Optical	1	60	2	0.3	1
1-117-0-L									Optical	3	180	6	0.9	3
1-117-1-Q									"Sion"	1	180	2	0.3	1
1-117-2-L									Optical	2	120	4	0.6	2
1-117-3-A									Optical	1	60	2	0.3	1
1-121-2-A									Optical	1	60	2	0.3	1
1-129-2-Q									Heat	2	100	4	0.6	2
1-145-2-Q									Heat	1	100	2	0.3	1
1-165-0-L									Optical	1	60	2	0.3	1
1-165-1-L									Optical	1	60	2	0.3	1
1-165-2-L									Optical	1	60	2	0.3	1
1-165-4-L									Optical	1	60	2	0.3	1
1-169-1-A									Optical	1	60	2	0.3	1
1-174-2-L									Heat	1	100	2	0.3	1
1-177-0-L									Optical	1	60	2	0.3	1
1-177-2-A									Optical	1	60	2	0.3	1
1-179-1-L									Optical	1	60	2	0.3	1
1-183-2-A					G	1	100	2	Optical	1	60	2	0.6	2
1-186-0-A									"Sion"	1	180	2	0.3	1
1-186-01-L									Optical	1	60	2	0.3	1
1-186-1-Q									"Sion"	1	180	2	0.3	1
1-186-2-Q									Optical	1	60	2	0.3	1
1-186-4-L									Heat	1	100	2	0.3	1
1-199-0-L									Optical	1	60	2	0.3	1
1-199-2-L									Optical	1	60	2	0.3	1
1-201-1-A									Optical	1	60	2	0.3	1
1-205-1-A									Optical	1	60	2	0.3	1
1-207-1-L									Optical	1	60	2	0.3	1
1-207-4-A									Optical	1	60	2	0.3	1
1-207-2-Q									Optical	1	60	2	0.3	1
1-207-3-E					G	1	100	2	Sion/exo	1	180	2	0.6	2
1-207-4-A									Optical	1	60	2	0.3	1
2-17-0-A									"Sion"	2	360	4	0.6	2
2-26-1-A									Optical	1	60	2	0.3	1
2-26-2-A									Optical	1	60	2	0.3	1
2-26-4-A									Optical	1	60	2	0.3	1
2-26-2-L									Optical	2	120	4	0.6	2
2-30-1-A									Optical	1	60	2	0.3	1
2-32-2-A									Optical	1	60	2	0.3	1
2-35-1-A									"Sion"	1	180	2	0.3	1
2-37-2-A									Optical	1	60	2	0.3	1
2-40-1-Q					G,H,T,N	4	400	8	Sion/exo	1	180	2	1.5	5
2-40-2-A									Optical	1	60	2	0.3	1
2-47-0-L									Optical	1	60	2	0.3	1
2-47-1-C									Optical	1	60	2	0.3	1
2-56-0-L									Optical	1	60	2	0.3	1
2-58-1-L									Heat	1	100	2	0.3	1
2-59-2-L									Heat	1	100	2	0.3	1

2-59-4-L									Optical	1	60	2	0.3	1
2-62-1-T									Optical	1	60	2	0.3	1
2-64-1-L									Optical	1	60	2	0.3	1
2-66-1-L									Optical	1	60	2	0.3	1
2-72-2-L									Optical	2	120	4	0.6	2
2-75-0-L									Heat	1	100		0.3	1
2-80-1-A									Optical	1	60	2	0.3	1
2-82-0-E	Sump	7	140	7	G,H,T,N	4	400		"Sion"	3	540	6	4.2	14
2-165-0-L									Optical	1	60	2	0.3	1
2-165-1-A									Optical	1	60	2	0.3	1
2-165-2-L									Optical	1	60	2	0.3	1
2-165-3-L									Optical	2	120	4	0.6	2
2-175-0-L									Optical	2	120	4	0.6	2
2-186-0-L									Optical	1	60	2	0.3	1
2-186-1-L									Optical	1	60	2	0.3	1
2-186-2-L									Optical	1	60	2	0.3	1
2-186-4-L									Optical	2	120	4	0.6	2
2-194-0-L									Optical	1	60	2	0.3	1
2-199-1-L									Optical	1	60	2	0.3	1
2-207-0-L									Optical	1	60	2	0.3	1
2-207-1-Q									Optical	1	60	2	0.3	1
2-207-2-A					G	1	100	2	"Sionexi"	1	180	2	0.6	2
2-207-3-A									"Sionexi"	2	360	4	0.6	2
2-214-2-M									"Sionexi"	1	180	2	0.3	1
2-214-4-M									"Sion"	1	180	2	0.3	1
2-221-1-A									Optical	1	60	2	0.3	1
2-228-1-F	Tank	1	1000	50										1
3-B-0-W	Tank	1	1000	50										1
3-12-0-W	Tank	1	1000	50										1
3-12-1-Q	Tank	1	1000	50										1
3-12-2-Q	Tank	1	1000	50										1
3-26-1-A	Sump	7	140	7					Optical	1	60	2	2.4	8
3-26-2-A	Sump	7	140	7					Optical	1	60	2	2.4	8
3-30-0-L	Sump	7	140	7					Optical	1	60	2	2.4	8
3-33-1-A	Sump	7	140	7					Optical	1	60	2	2.4	8
3-33-2-A	Sump	7	140	7					Optical	1	60	2	2.4	8
3-40-0-A	Sump	7	140	7					Optical	1	60	2	2.4	8
3-40-2-A	Sump	7	140	7					Optical	1	60	2	2.4	8
3-47-0-C	Sump	7	140	7					Optical	1	60	2	2.4	8
3-62-2-L	Sump	7	140	7					Optical	1	60	2	2.4	8
3-82-0-E	Sump	7	140	7	G,H,T,N	4	400	8	"Sion"	2	360	4	3.9	13
3-103-0-E	Sump	7	140	7	G,H,T,N	4	400	8	"Sion"	4	720	8	4.5	15
3-152-0-C	Sump	7	140	7	G,H,T,N	4	400	8	"Sion"	2	360	4	3.9	13
3-152-2-Q	Sump	7	140	7	G,H,T,N	4	400	8	"Sion"	1	180	2	3.6	12
3-160-2-L	Sump	7	140	7					Optical	1	60	2	2.4	8
3-165-1-T	Tank	1	1000	50					Optical	1	60	2	0.6	2
3-165-2-F	Tank	1	1000	50									0.3	1
3-174-0-A	Sump	7	140	7					Optical	1	60	2	2.4	8
3-174-2-A	Sump	7	140	7					Optical	1	60	2	2.4	8
3-190-1-J	Tank	1	1000	50									0.3	1
3-190-2-J	Tank	1	1000	50									0.3	1
3-228-0-E	Sump	7	140		G,H,T,N	4	400	8	Sion/exi	2	360	4	3.9	13
4-F-0-V	Tank	1	1000	50									0.3	1
4-12-0-F	Tank	1	1000	50									0.3	1
4-26-1-F	Tank	1	1000	50									0.3	1
4-26-2-F	Tank	1	1000	50									0.3	1
4-47-1-F	Tank	1	1000	50									0.3	1
4-47-2-F	Tank	1	1000	50									0.3	1
4-75-0-Q	Sump	7	140										2.1	7
4-75-1-W	Tank	1	1000	50									0.3	1
4-75-2-W	Tank	1	1000	50									0.3	1
4-78-1-W	Tank	1	1000	50									0.3	1
4-78-2-W	Tank	1	1000	50									0.3	1
4-82-0-F	Tank	1	1000	50									0.3	1
4-82-1-F	Tank	1	1000	50									0.3	1
4-82-2-F	Tank	1	1000	50									0.3	1
4-94-1-W	Tank	1	1000	50									0.3	1
4-96-0-W	Tank	1	1000	50									0.3	1
4-103-0-F	Tank	1	1000	50									0.3	1
4-103-1-W	Tank	1	1000	50									0.3	1
4-130-2-W	Tank	1	1000	50									0.3	1

4-162-0-F	Tank	1	1000	50									0.3	1
4-162-1-F	Tank	1	1000	50									0.3	1
4-162-2-F	Tank	1	1000	50									0.3	1
4-165-1-F	Tank	1	1000	50									0.3	1
4-165-2-F	Tank	1	1000	50									0.3	1
4-165-3-F	Tank	1	1000	50									0.3	1
4-165-4-F	Tank	1	1000	50									0.3	1
4-169-0-A	Sump	7	140	7					Optical	4	240	8	3.3	11
4-169-1-W	Tank	1	1000	50									0.3	1
4-169-2-W	Tank	1	1000	50									0.3	1
4-186-0-E	Sump	7	140	7	G,H,T,N	4	400	8	Sion/exi	2	360	4	3.9	13
4-186-1-J	Tank	1	1000	50									0.3	1
4-186-2-J	Tank	1	1000	50									0.3	1
4-190-1-J	Tank	1	1000	50									0.3	1
4-190-2-J	Tank	1	1000	50									0.3	1
4-207-0-F	Tank	1	1000	50									0.3	1
4-207-1-F	Tank	1	1000	50									0.3	1
4-207-2-F	Tank	1	1000	50									0.3	1
4-228-0-Q	Sump	7	140	7									2.1	7
4-228-1-W	Tank	1	1000	50									0.3	1
4-228-2-W	Tank	1	1000	50									0.3	1
4-242-0-W	Tank	1	1000	50									0.3	1
Totals		200	49080	2440		45	4500	82		199	18320	396	131.7	444

B. WATER MIST SPRINKLER CALCULATIONS

	Pipe Dimensions	WM	Quantity	Sprinkler	Weight	Weight	Cost
Number	Pipe type	Required	(ft)	number	(lb/ft)	(lb)	($)
				(3lb/each)			
03 level	None	NO	0	0	3.46	0	0
02 Level	None	NO	0	0	3.46	0	0
01 Level	1 1/2" Main ->12.8	Yes	70	0	3.46	242.2	896
Main Deck	1 1/2" Main ->12.8	Yes	250	0	3.46	865	3200
2nd Deck	1 1/2" Main ->12.8	Yes	250	0	3.46	865	3200
3rd Deck	1 1/2" Main ->12.8	Yes	135	0	3.46	467.1	1728
	Total w/o water					2439.3	9024
	Total with water					1867.99	
03 level	None	NO	0	0	1.71	0	0
02 Level	None	NO	0	0	1.71	0	0
01 Level	3/4" Branch ->12.8	Yes	85	0	1.71	145.35	1088
Main Deck	3/4" Branch ->12.8	Yes	420	0	1.71	718.2	5376
2nd Deck	3/4" Branch ->12.8	Yes	425	0	1.71	726.75	5440
3rd Deck	3/4" Branch ->12.8	Yes	125	0	1.71	213.75	1600
	Total Weight added w/o Water					1804.05	13504
	Total Weight added with Water					345.381	
2nd Deck	Water mist supply Tank and pump	Yes	0	0	0	1000	1000
	Compartment	WM	Quantity	Sprinklers	Weight	Total	Cost
Number	Noun Name	Required	(ft)	Required	(lb)	(lb)	($)
				(3lb/each)			
5-99-0-T	Mast	NO	0	0	2.00	0	0
03-97-0-Q	Signalman's Shelter	NO	0	0	2.00	0	0
02-45-0-Q	Fan Space	NO	0	0	2.00	0	0
02-48-0-Q	Pilothouse	NO	0	0	2.00	0	0
02-63-0-C	Sensor Room & Command Support Center	NO	0	0	2.00	0	0
02-63-2-L	Passageway	NO	0	0	2.00	0	0
02-72-2-L	Sanitary Space	NO	0	0	2.00	0	0
02-73-1-Q	Antenna Array Plenum, Stbd	NO	0	0	2.00	0	0
02-73-2-Q	Antenna Array Plenum, Port	NO	0	0	2.00	0	0
02-96-0-M	Small Arms Locker	NO	0	0	2.00	0	0
02-106-0-Q	Electronics Equipment Space & Storeroom	NO	0	0	2.00	0	0
02-106-1-Q	Stack, Stbd	NO	0	0	2.00	0	0
02-106-2-Q	Stack, Port	NO	0	0	2.00	0	0
01-47-1-L	Vestibule	YES	0	1	2.00	2	10
01-47-2-L	Executive Officer's Stateroom	YES	0	1	2.00	2	10
01-47-3-L	Commanding Officers Sanitary Space	YES	0	1	2.00	2	10
01-47-4-L	EO & XO Sanitary Space	YES	0	1	2.00	2	10
01-47-5-L	Commanding Officers Stateroom	YES	0	1	2.00	2	10
01-52-0-L	Passageway	YES	0	1	2.00	2	10
01-52-1-A	Locker	NO	0	0	2.00	0	0
01-58-2-L	Engineering Officers Stateroom	YES	0	1	2.00	2	10

01-61-1-Q	Commanding Officers Office	YES	0	1	2.00	2	10
01-68-0-L	Wardroom Stateroom	YES	0	1	2.00	2	10
01-68-01-L	Passageway	YES	0	1	2.00	2	10
01-68-1-L	Wardroom Stateroom	YES	0	1	2.00	2	10
01-68-2-L	Sanitary Space	YES	0	1	2.00	2	10
01-68-4-L	Wardroom Stateroom	YES	0	1	2.00	2	10
01-81-1-L	Sanitary Space	YES	0	1	2.00	2	10
01-82-1-L	Passenger Stateroom	YES	0	1	2.00	2	10
01-84-2-L	Wardroom Stateroom	YES	0	1	2.00	2	10
01-85-0-L	Wardroom Stateroom	YES	0	1	2.00	2	10
01-89-2-L	Sanitary Space	YES	0	1	2.00	2	10
01-94-1-L	Passageway	YES	0	1	2.00	2	10
01-94-2-L	Decontamination Shower	NO	0	0	2.00	0	0
01-95-1-Q	Winch Machinery Space	YES	0	1	2.00	2	10
01-98-0-L	Decontamination Space	YES	0	1	2.00	2	10
01-103-0-Q	Avionics Workshop	YES	0	1	2.00	2	10
01-103-1-Q	Machinery Vent Plenum Compartment	NO	0	0	2.00	0	0
01-103-2-Q	Machinery Vent Plenum Compartment	NO	0	0	2.00	0	0
01-109-1-Q	Uptake	NO	0	0	2.00	0	0
01-109-2-Q	Uptake	NO	0	0	2.00	0	0
01-117-0-Q	Helicopter Hanger	NO	0	0	2.00	0	0
1-J-0-K	Flamable Liquid Stores	NO	0	0	2.00	0	0
1-12-0-Q	Anchor Windlass Room & Boatswains Shop	YES	0	1	2.00	2	10
1-26-0-M	76MM Magazine	NO	0	0	2.00	0	0
1-26-1-C	Gun Control Panel Room	YES	0	1	2.00	2	10
1-26-2-L	Passageway	YES	0	1	2.00	2	10
1-43-2-Q	Fan Room	NO	0	0	2.00	0	0
1-47-0-L	Passageway	YES	0	1	2.00	2	10
1-47-1-Q	Laundry	YES	0	1	2.00	2	10
1-51-2-L	Sanitary Space	YES	0	1	2.00	2	10
1-53-1-A	Locker	NO	0	0	2.00	0	0
1-56-1-A	Locker	NO	0	0	2.00	0	0
1-58-1-L	Crews Locker Space	YES	0	1	2.00	2	10
1-61-2-L	Crews Berthing	YES	0	1	2.00	2	10
1-62-2-A	Seabag Locker	YES	0	1	2.00	2	10
1-65-2-A	Foul Weather Gear & Life Vest Locker	YES	0	1	2.00	2	10
1-73-1-Q	Engineers Office & Damage Control Central	YES	0	1	2.00	2	10
1-82-1-L	Passageway	YES	0	1	2.00	2	10
1-82-2-A	Forward Repair 2	YES	0	1	2.00	2	10
1-82-3-Q	Ships & Supply Office	YES	0	1	2.00	2	10
1-82-4-Q	Engineers Workshop	YES	0	1	2.00	2	10
1-90-2-Q	Electricians Workshop	YES	0	1	2.00	2	10
1-95-1-A	Life Jacket Locker	YES	0	1	2.00	2	10
1-96-1-L	Passageway	YES	0	1	2.00	2	10
1-103-1-L	Passageway	YES	0	1	2.00	2	10
1-103-2-L	Vestibule	YES	0	1	2.00	2	10
1-103-3-A	Electronic Stores	YES	0	1	2.00	2	10
1-103-3-Q	Uptake	NO	0	0	2.00	0	0
1-103-4-A	Engineers Tool Room	YES	0	1	2.00	2	10
1-103-4-Q	Uptake	NO	0	0	2.00	0	0

1-113-2-L	Passageway	YES	0	1	2.00	2	10
1-117-0-L	Crews Mess	YES	0	0	2.00	0	0
1-117-1-Q	Fan Room	NO	0	0	2.00	0	0
1-117-2-L	Wardroom	YES	0	1	2.00	2	10
1-117-3-A	Recreation Locker	YES	0	1	2.00	2	10
1-121-2-A	Ships Store	YES	0	1	2.00	2	10
1-129-2-Q	Scullery	YES	0	1	2.00	2	10
1-145-2-Q	Galley	YES	0	1	2.00	2	10
1-165-0-L	Passageway	YES	0	1	2.00	2	10
1-165-1-L	CPO Lounge	YES	0	1	2.00	2	10
1-165-2-L	CPO Stateroom	YES	0	1	2.00	2	10
1-165-4-L	CPO Stateroom	YES	0	1	2.00	2	10
1-169-1-A	Medical Locker	NO	0	0	2.00	0	0
1-174-2-L	Sanitary Space	YES	0	1	2.00	2	10
1-177-0-L	CPO Stateroom	YES	0	1	2.00	2	10
1-177-2-A	Linen Locker	NO	0	0	2.00	0	0
1-179-1-L	Dispensary	YES	0	1	2.00	2	10
1-183-2-A	Cleaning Gear Locker	NO	0	0	2.00	0	0
1-186-0-A	Electricians Stores	YES	0	1	2.00	2	10
1-186-01-L	Passageway	YES	0	1	2.00	2	10
1-186-1-Q	Trash Compactor Room	YES	0	1	2.00	2	10
1-186-2-Q	Computer Room	YES	0	1	2.00	2	10
1-186-4-L	Sanitary Space	YES	0	1	2.00	2	10
1-199-0-L	CPO Stateroom	YES	0	1	2.00	2	10
1-199-2-L	CPO Stateroom	YES	0	1	2.00	2	10
1-201-1-A	Life Jacket Locker	YES	0	1	2.00	2	10
1-205-1-A	Foul Weather Gear & Life Vest Locker	YES	0	1	2.00	2	10
1-207-1-L	Vestibule	YES	0	1	2.00	2	10
1-207-4-A	Boat Ops Locker	YES	0	1	2.00	2	10
1-207-2-Q	Fan Room	YES	0	1	2.00	2	10
1-207-3-E	JP-5 Fueling Station	YES	0	1	2.00	2	10
1-207-4-A	Boat Gear Locker	YES	0	1	2.00	2	10
2-17-0-A	Boatswains Stores	YES	0	1	2.00	2	10
2-26-1-A	Unassigned Stores	YES	0	1	2.00	2	10
2-26-2-A	Small Stores Locker	YES	0	1	2.00	2	10
2-26-4-A	Ships Storeroom	YES	0	1	2.00	2	10
2-28-2-L	Passageway	YES	0	1	2.00	2	10
2-30-1-A	General Stores	YES	0	1	2.00	2	10
2-32-2-A	Master At Arms Storeroom	YES	0	1	2.00	2	10
2-35-1-A	Engineers Stores	YES	0	1	2.00	2	10
2-37-2-A	Navigation Storeroom	YES	0	1	2.00	2	10
2-40-1-Q	Ordnance Workshop	YES	0	1	2.00	2	10
2-40-2-A	CPO Baggage Locker	YES	0	1	2.00	2	10
2-47-0-L	Crews Berthing	YES	0	1	2.00	2	10
2-47-1-C	Interior Communications Room	YES	0	1	2.00	2	10
2-56-0-L	Passageway	YES	0	1	2.00	2	10
2-58-1-L	Crews Sanitary Space	YES	0	1	2.00	2	10
2-59-2-L	Sanitary Space	YES	0	1	2.00	2	10
2-59-4-L	Crews Locker Space	YES	0	1	2.00	2	10
2-62-1-T	WT Wire way / AC Trunk	NO	0	0	2.00	0	0
2-64-1-L	Crews Locker Space	YES	0	1	2.00	2	10
2-66-1-L	Crews Berthing	YES	0	1	2.00	2	10
2-72-2-L	Crews Lounge	YES	0	1	2.00	2	10

2-75-0-L	Sanitary Space	YES	0	1	2.00	2	10
2-80-1-A	Cleaning Gear Locker	NO	0	0	2.00	0	0
2-82-0-E	Auxiliary Machinery Space No. 1	YES	0	1	2.00	2	10
2-165-0-L	Sanitary Space	YES	0	1	2.00	2	10
2-165-1-A	Sea Bag Locker	YES	0	1	2.00	2	10
2-165-2-L	Crews Lounge	YES	0	1	2.00	2	10
2-165-3-L	Crews Berthing	YES	0	1	2.00	2	10
2-175-0-L	Crews Locker Space	YES	0	1	2.00	2	10
2-186-0-L	Sanitary Space	YES	0	1	2.00	2	10
2-186-1-L	Crews Lounge	YES	0	1	2.00	2	10
2-186-2-L	Sea Bag Locker	YES	0	1	2.00	2	10
2-186-4-L	Crews Berthing	YES	0	1	2.00	2	10
2-194-0-L	Crews Locker Space	YES	0	1	2.00	2	10
2-199-1-L	Vestibule	YES	0	1	2.00	2	10
2-207-0-L	Passageway	YES	0	1	2.00	2	10
2-207-1-Q	Fan Room	NO	0	0	2.00	0	0
2-207-2-A	Aviation Stores	YES	0	1	2.00	2	10
2-207-3-A	Hawser & Rescue Equipment Stowage	YES	0	1	2.00	2	10
2-214-2-M	Small Arms Magazine	YES	0	1	2.00	2	10
2-214-4-M	Engineers Stores	YES	0	1	2.00	2	10
2-221-1-A	Aft Repair 3	YES	0	1	2.00	2	10
2-228-1-F	Emergency Generator Diesel Oil Tank	Tank	0	0	2.00	0	0
3-B-0-W	Potable Clean Ballast Tank	Tank	0	0	2.00	0	0
3-12-0-W	Chain Locker Sump	Tank	0	0	2.00	0	0
3-12-1-Q	Chain Locker	Tank	0	0	2.00	0	0
3-12-2-Q	Chain Locker	Tank	0	0	2.00	0	0
3-26-1-A	Wardroom Stores	Sump	0	0	2.00	0	0
3-26-2-A	Unassigned Stores	Sump	0	0	2.00	0	0
3-30-0-L	Passageway	Sump	0	0	2.00	0	0
3-33-1-A	Unassigned Stores	Sump	0	0	2.00	0	0
3-33-2-A	Unassigned Stores	Sump	0	0	2.00	0	0
3-40-0-A	Engineers Stores	Sump	0	0	2.00	0	0
3-40-2-A	Unassigned Stores	Sump	0	0	2.00	0	0
3-47-0-C	Communication Center	Sump	0	0	2.00	0	0
3-62-2-L	Vestibule	Sump	0	0	2.00	0	0
3-82-0-E	Auxiliary Machinery Room No. 2	Sump	0	0	2.00	0	0
3-103-0-E	Engine Room	Sump	0	0	2.00	0	0
3-152-0-C	Engineering Control Center	Sump	0	0	2.00	0	0
3-152-2-Q	Engineers Work Space	Sump	0	0	2.00	0	0
3-160-2-L	Sanitary Space	Sump	0	0	2.00	0	0
3-165-1-T	Service Elevator Trunk	Tank	0	0	2.00	0	0
3-165-2-F	Lube Oil Tank	Tank	0	0	2.00	0	0
3-174-0-A	Deep Freeze	Sump	0	0	2.00	0	0
3-174-2-A	Vegetable Storage	Sump	0	0	2.00	0	0
3-190-1-J	JP-5 Service Tank	Tank	0	0	2.00	0	0
3-190-2-J	JP-5 Service Tank	Tank	0	0	2.00	0	0
3-228-0-E	Steering Gear Room	Sump	0	0	2.00	0	0
4-F-0-V	Inaccessible Void	Tank	0	0	2.00	0	0
4-12-0-F	Diesel Oil Tank	Tank	0	0	2.00	0	0
4-26-1-F	Diesel Oil Tank	Tank	0	0	2.00	0	0
4-26-2-F	Diesel Oil Tank	Tank	0	0	2.00	0	0

4-47-1-F	Diesel Oil Tank	Tank	0	0	2.00	0	0
4-47-2-F	Diesel Oil Tank	Tank	0	0	2.00	0	0
4-75-0-Q	Transducer Well	Sump	0	0	2.00	0	0
4-75-1-W	Clean Ballast Tank	Tank	0	0	2.00	0	0
4-75-2-W	Clean Ballast Tank	Tank	0	0	2.00	0	0
4-78-1-W	Potable Water Tank	Tank	0	0	2.00	0	0
4-78-2-W	Potable Water Tank	Tank	0	0	2.00	0	0
4-82-0-F	Diesel Oil Tank	Tank	0	0	2.00	0	0
4-82-1-F	Diesel Oil Tank	Tank	0	0	2.00	0	0
4-82-2-F	Diesel Oil Tank	Tank	0	0	2.00	0	0
4-94-1-W	Feedwater Drain Storage Tank	Tank	0	0	2.00	0	0
4-96-0-W	Diesel Oil Overflow Tank	Tank	0	0	2.00	0	0
4-103-0-F	Diesel Oil Tank	Tank	0	0	2.00	0	0
4-103-1-W	Clean Ballast Tank	Tank	0	0	2.00	0	0
4-130-2-W	Clean Ballast Tank	Tank	0	0	2.00	0	0
4-162-0-F	Hydraulic Oil Tank	Tank	0	0	2.00	0	0
4-162-1-F	CPCH Sump Tank	Tank	0	0	2.00	0	0
4-162-2-F	CPCH Sump Tank	Tank	0	0	2.00	0	0
4-165-1-F	Oily Waste Holding Tank	Tank	0	0	2.00	0	0
4-165-2-F	Diesel Oil Overflow Tank	Tank	0	0	2.00	0	0
4-165-3-F	Diesel Oil Service Tank	Tank	0	0	2.00	0	0
4-165-4-F	Diesel Oil Service Tank	Tank	0	0	2.00	0	0
4-169-0-A	Refrigerated & Dry Stores	Sump	0	0	2.00	0	0
4-169-1-W	Clean Ballast Tank	Tank	0	0	2.00	0	0
4-169-2-W	Clean Ballast Tank	Tank	0	0	2.00	0	0
4-186-0-E	JP-5 Pump Room	Sump	0	0	2.00	0	0
4-186-1-J	JP-5 Drain Tank	Tank	0	0	2.00	0	0
4-186-2-J	JP-5 Overflow Tank	Tank	0	0	2.00	0	0
4-190-1-J	JP-5 Storage Tank	Tank	0	0	2.00	0	0
4-190-2-J	JP-5 Storage Tank	Tank	0	0	2.00	0	0
4-207-0-F	Diesel Oil Tank	Tank	0	0	2.00	0	0
4-207-1-F	Diesel Oil Tank	Tank	0	0	2.00	0	0
4-207-2-F	Diesel Oil Tank	Tank	0	0	2.00	0	0
4-228-0-Q	Tactas Gear Winch Well	Sump	0	0	2.00	0	0
4-228-1-W	Clean Ballast Tank	Tank	0	0	2.00	0	0
4-228-2-W	Clean Ballast Tank	Tank	0	0	2.00	0	0
4-242-0-W	Clean Ballast Tank	Tank	0	0	2.00	0	0
Totals	**Totals with out water**					5463	$ 24,628
	Totals with water					6351	

C. ISOLATION SYSTEM - DOORS ADDITION

Hatches	Closure	Changed	Type	Weight	Volume	Electrical	Cost	Vcg	Lcg	Vcg	Lcg
				Added	Added	Load					
				(lbs)	(ft^2)	Amps	($)				
2-45-2	X	Yes	Hydraulic	250	4	15	5000	16	90	4000	22500
2-63-2	Z	Yes	Hydraulic	250	4	15	5000	16	72	4000	18000
2-181-2	(Y)	Yes	Hydraulic	250	4	15	5000	16	-46	4000	-11500
2-200-1	(X)	Yes	Hydraulic	250	4	15	5000	16	-65	4000	-16250
1-24-1	X	Yes	Hydraulic	250	4	15	5000	24	111	6000	27750
1-44-2	X	Yes	Hydraulic	250	4	15	5000	24	91	6000	22750
1-64-2	Z	Yes	Hydraulic	250	4	15	5000	24	71	6000	17750
1-84-2	Y	Yes	Hydraulic	250	4	15	5000	24	51	6000	12750
1-97-3	Z	Yes	Hydraulic	250	4	15	5000	24	38	6000	9500
1-109-2	Z	Yes	Hydraulic	250	4	15	5000	24	26	6000	6500
1-180-1	Z	Yes	Hydraulic	250	4	15	5000	24	-45	6000	-11250
1-201-1	Z	Yes	Hydraulic	250	4	15	5000	24	-66	6000	-16500
1-211-1	Z	Yes	Hydraulic	250	4	15	5000	24	-76	6000	-19000
1-216-2	X	No	WTH	0	0	0	0	24	-81	0	0
1-244-1	Y	No	WTH	0	0	0	0	24	-109	0	0
01-24-1	Y	No	QAWTH	0	0	0	0	32	111	0	0
01-44-2	Y	No	WTH	0	0	0	0	32	91	0	0
01-162-1	X	No	WTH	0	0	0	0	32	-27	0	0
Doors											
3-68-2	unclass	No	FUMETD	0	0	0	0	8	67	0	0
3-151-1	unclass	No	FUMETD	0	0	0	0	8	-16	0	0
3-151-2	unclass	No	FUMETD	0	0	0	0	8	-16	0	0
3-151-4	unclass	No	FUMETD	0	0	0	0	8	-16	0	0
3-169-1	X	No	QAWTD	0	0	0	0	8	-34	0	0
2-42-2	Z	No	WTD	0	0	0	0	16	93	0	0
2-103-1	CX	No	HDWTD	0	0	0	0	16	32	0	0
2-198-1	Z	No	QAWTD	0	0	0	0	16	-63	0	0
2-217-2	X	No	WTD	0	0	0	0	16	-82	0	0
2-228-2	CY	Yes	Hydraulic	250	4	15	3000	16	-93	4000	-23250
1-12-0	X	Yes	Hydraulic	250	4	15	3000	24	123	6000	30750
1-26-2	CY	Yes	Hydraulic	250	4	15	3000	24	109	6000	27250
1-27-1	CX	No	QAWTD	0	0	0	0	24	108	0	0
1-35-2	CX	No	QAWTD	0	0	0	0	24	100	0	0
1-47-2	CZ	Yes	Hydraulic	250	4	15	3000	24	88	6000	22000
1-82-1	CZ	Yes	Hydraulic	250	4	15	3000	24	53	6000	13250
1-103-1	CZ	Yes	Hydraulic	250	4	15	3000	24	32	6000	8000
1-103-2	Z	Yes	Hydraulic	250	4	15	3000	24	32	6000	8000
1-103-3	X	Yes	Hydraulic	250	4	15	3000	24	32	6000	8000
1-104-0	unclass	No	FTD	0	0	0	0	24	31	0	0
1-165-1	CX	Yes	Hydraulic	250	4	15	3000	24	-30	6000	-7500
1-165-3	CZ	Yes	Hydraulic	250	4	15	3000	24	-30	6000	-7500
1-186-1	CZ	Yes	Hydraulic	250	4	15	3000	24	-51	6000	-12750
1-196-1	X	No	WTD	0	0	0	0	24	-61	0	0

1-196-2	Z	No	QAWTD	0	0	0	0	24	-61	0	0
1-207-1	CZ	Yes	Hydraulic	250	4	15	3000	24	-72	6000	-18000
1-208-2	X	No	WTD	0	0	0	0	24	-73	0	0
1-214-1	CZ	No	QAWTD	0	0	0	0	24	-79	0	0
1-214-3	CX	No	WTD	0	0	0	0	24	-79	0	0
01-47-1	Z	No	QAWTD	0	0	0	0	24	88	0	0
01-52-1	Z	No	QAWTD	0	0	0	0	24	83	0	0
01-101-1	CZ	No	QAWTD	0	0	0	0	24	34	0	0
01-103-1	CZ	Yes	Hydraulic	250	4	15	3000	24	32	6000	8000
01-103-2	X	No	WTD	0	0	0	0	24	32	0	0
01-103-3	X	No	WTD	0	0	0	0	24	32	0	0
01-103-4	CZ	No	QAWTD	0	0	0	0	24	32	0	0
01-103-5	Z	No	QAWTD	0	0	0	0	24	32	0	0
01-117-1	CX	Yes	Hydraulic	250	4	15	3000	24	18	6000	4500
02-59-1	CW	No	WEATD	0	0	0	0	32	76	0	0
02-59-2	CW	No	WEATD	0	0	0	0	32	76	0	0
02-69-2	Z	No	WEATD	0	0	0	0	32	66	0	0
02-75-2	X	No	FUMETD	0	0	0	0	32	60	0	0
02-98-1	X	No	WEATD	0	0	0	0	32	37	0	0
02-98-2	X	No	WEATD	0	0	0	0	32	37	0	0
02-103-0	CX	No	WEATD	0	0	0	0	32	32	0	0
02-106-0	Z	No	WEATD	0	0	0	0	32	29	0	0
02-119-2	CX	No	WEATD	0	0	0	0	32	16	0	0
03-97-0	CX	No	WEATD	0	0	0	0	40	38	0	0
Totals			**Additional Weight**	6750							
			Lts	3.01						152000	123750
Modified										68	55
Fittings	26			**Additional Volume**	108	**(ft^2)**				17	14
									Δ Vcg	-0.6710	
					Additional Electrical	405	Amps		**Δ Lcg**		-0.0068
						47	KVA				
						Cost	$ 107,000				

D. COMPUTERS AND PROCESSING ADDITIONS

Item	Location	Weight	Volume	Electrical	Cost
		Added	Added	Load	
		(lbs)	(ft2)	Amps	($)
Control Console	Pilothouse	300	24	9	10000
Control Console	Comms Center	300	24	9	10000
Control Console	Damage Control Central	300	24	9	10000
Control Console	Engineering Control	300	24	9	10000
Processing/Data Acquisition Unit	Pilothouse	75	7	3	4000
Processing/Data Acquisition Unit	01 level	75	7	3	4000
Processing/Data Acquisition Unit	Main Deck Bulkhead 12	75	7	3	4000
Processing/Data Acquisition Unit	Main Deck Bulkhead 26	75	7	3	4000
Processing/Data Acquisition Unit	Main Deck Bulkhead 47	75	7	3	4000
Processing/Data Acquisition Unit	Main Deck Bulkhead 82	75	7	3	4000
Processing/Data Acquisition Unit	Main Deck Bulkhead 103	75	7	3	4000
Processing/Data Acquisition Unit	Main Deck Bulkhead 117	75	7	3	4000
Processing/Data Acquisition Unit	Main Deck Bulkhead 165	75	7	3	4000
Processing/Data Acquisition Unit	Main Deck Bulkhead 186	75	7	3	4000
Processing/Data Acquisition Unit	Main Deck Bulkhead 207	75	7	3	4000
Processing/Data Acquisition Unit	2nd Deck Bulkhead 228	75	7	3	4000
Totals	**Weight added**	2100	Lbs		
	lts	0.94	**lts**		
		Volume added	180	ft^2	
			Electrical	72	**Amps**
				Cost	$ 88,000

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